1987
Get Away Special
Experimenter's
Symposium

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CONTENTS

Page

CONTENTS (Continued)

MICROGRAVITY RESEARCH AT THE UNIVERSITY OF MEXICO:

EXPERIMENTS IN PAYLOAD G-006

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ABSTRACT

This paper describes in some detail the experiments contained in the G-006 payload related to: thin film vapor deposition, vacuum variations in a chamber vented to space, solidification of a Zn-Al-Cu alloy, and multiple-location temperature monitoring for thermal model validation. A discussion of the expected results is presented, together with the methods selected to conduct the postflight analysis, and finally, a overview of our future activities in this field.

INTRODUCTION

In July of 1985, a group of researchers from the National University of Mexico (UNAM), started the development of our first set of automatic microgravity experiments. To ensure a diligent start, the project was begun with the assistance of experienced personnel from Utah State University (USU). The payload, G-006, was manifested as a backup for a March 6, 1986 flight, and has since been awaiting preflight certification at KSC.

The payload consists of several university experiments: four from UNAM, described here, and one from each: USU, the Florida Institute of Technology and the U. of Arizona, which will be published independently.

Microgravity research, as well as other activities in earth orbit, are seen as topics of considerable importance for the present and future advancement of scientific and technological frontiers; even though, their full implications are still a matter wide open to discussion. However, it is clear that orbital activities will grow steadily in the coming years, and that no country concerned with the future can afford to remain aside. Thus, the University of Mexico, through its Interdisciplinary Group on Space Activities (GIAE), has focused its attention in the development of microgravity science, satellite technology and extraatmospheric observations of earth and space. Consequently, this project is the first of several others, that allow for the initiation of such efforts, with a set of experiments tailored

1

both: to solve problems of local importance, and to acquire the technological know-how for preparing self-contained space payloads.

The SSCP program at NASA represents, in our view, a novel and cost-effective opportunity to conduct exploratory microgravity research, as well as certain earth/space observations; specially for a country that has no present plans for rocket development.

Experiments included in G-006 were selected from a set of twelve, that covered those many fields of research. Among them, we chose an alloy solidification as a diagnostic method for microstructural formation, an epitaxial growth of a solid to solid interface for basic studies relevant to microelectronics, and two support measurements of temperature and vacuum for immediate use in the experiments, and also of future value in the design of later devices. In a second canister, G-599, we follow a plan to develop more elaborate biomedical, remote sensing and other experiments we are presently integrating.

EXPERIMENTAL ARRANGEMENT

The general arrangement of experiments in this 90kg canister is based in a multilayered sequence, five in all, of which the top four are occupied by the UNAM experiments. Each experiment is contained in a fibre glass hexagonal structure that provides: thermal isolation from the outside, protects the internal experiments, and also, structural fixtures for the various devices (see details in ref.1). The hexagons fit in a 48.2cm diameter circle. Two of the structures are 17.7cm tall, one 12.7 and the other two 10.4cm. All structures are held together by an aluminum structure which bolts to the canister mounting plate using the NASA provided 48cm bolt circle. Three bumpers at the bottom of the payload provide lateral stability to the structure.

A block diagram is provided in Fig 1 to illustrate the disposition of the hardware within the container. The experiments will be individually described in some detail in the next few sections.
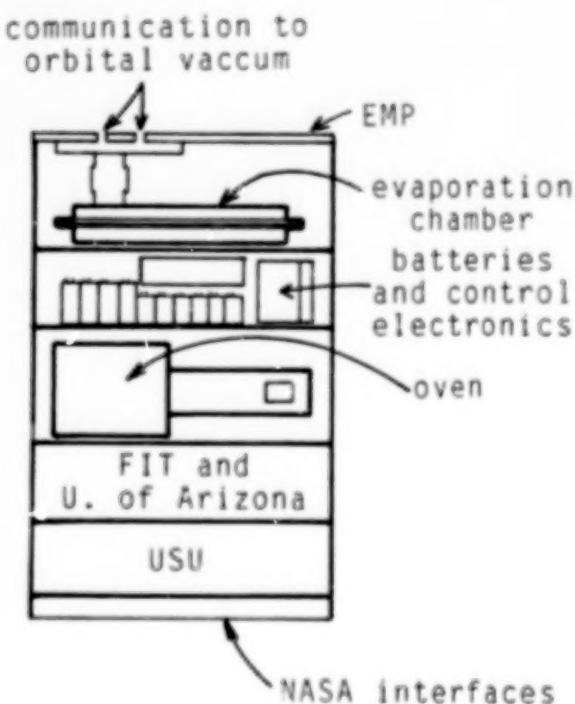

Figure 1. Disposition of hardware within the SSCP canister.

Vapor Deposition Experiment

Attached to the experimenters mounting plate supplied by NASA we have a fixture provided with a bellow that is free to purge into space during ascent

2

and orbital flight, through a filter installed to avoid possible contamination of the Shuttle environment. Immediately following, is the cold cathode vacuum detector of the chamber, where the evaporation of Al will be carried out onto a set of substrates, that include monocrystalline Si, Cu, GaAs, Ag and Silicon oxide. The substrates are mounted on a ceramic heating element for controlled heat treatment during and after vapor deposition (ref.2). The chamber is composed of three independent lobes, where evaporation of different amounts of Al may occur in a controlled sequence onto similar groups of crystals (see fig.2).

The Al is placed in a tungsten wire basket through which current can flow from a battery source in order to heat the metal until its evaporation is completed, whilst the substrates are fixed to the ceramic holders that may heat the crystals at the time or at a later period. Power to the heaters, and the evaporation source is controlled by a set of Mosfet transistors, that switch to on/off, instead of relays; since these suffer from carbon build-up at the contact points, with subsequent mechanical failure. Power is fed in short pulse trains to both heaters, thus saving energy, since such transistors consume little current when active and no current when open. Temperature sensors, thermocouples, are detecting the temperature of the substrate heaters in order to control the heat treatment parameters. All signals are monitored and controlled by an onboard microcomputer based on a 65C02 microprocessor with 16 analog input and 8 output ports. It is also equipped with several memories, 16K of Eprom for program and data storage for postflight analysis, as well as 8K of Ram for onboard preprocessing and temporary data management.

The controller may be placed on standby when no action is required. The program is driven by a table installed in ROM which stores the time at which each action must take place, and the function which must be performed. The table entry also contains information with respect to repetitive operations or sets of operations. This permanent table in ROM allows for the controller to be deactivated when a minimum amount of time is available during which no action is required. A survey of previous experiments indicates that this measure reduces the average power consumption by three or more orders of magnitude on most
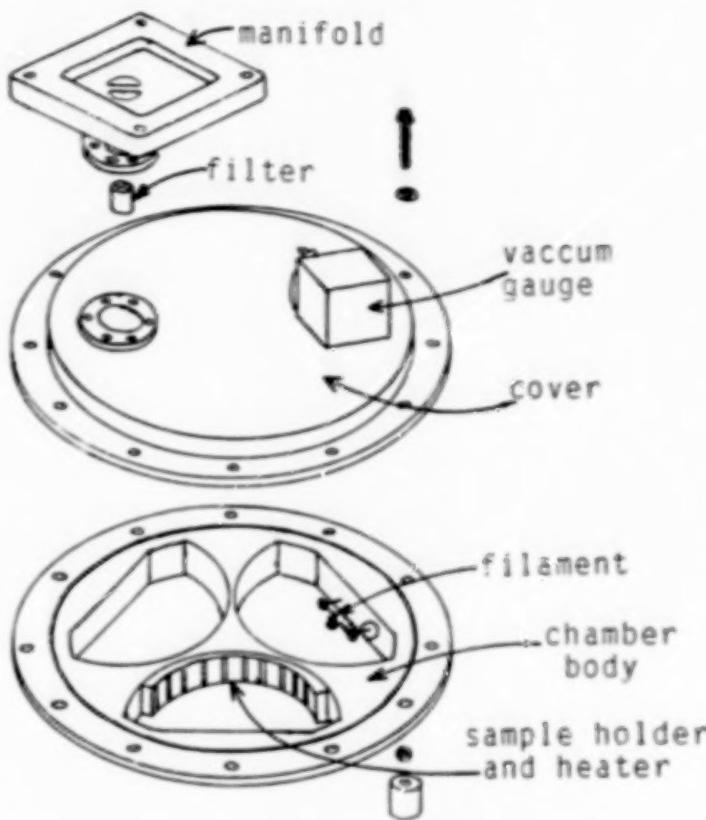
Figure 2. Diagram of metal evaporation chamber.

experiments. In order for the controller to be reactivated after a standby period, a clock provides an internal alarm pulse at the time of the next required action. The clock chosen uses approximately 60 microwatts of power. The controller performs the following functions under the command of its table driven program: It monitors up to 16 voltage sources through a multiplexer and an A/D converter (8bits), it can send up to 8 separate voltage pulses; each line has a driver on it capable of supplying three amperes of current, and it stores up to 32k bytes of data for later analysis. The power consumption when active is approximately 120 milliwatts except when performing I/O operations. Identical controllers are used in each of the three active experiments.

Solidification Experiment

The metal studied is a Zn,Al,Cu alloy that is presently under industrial development in our country, however, certain microstructural properties of this superplastic metal remain a topic of study. In the microgravity environment, with an absence of convection currents and crucible contact effects, we expect to produce a sample where the impurities are the sole determining factor of the microstructure; since the other factor participating in the process, the cooling rate, is a controlled variable in this experiment. See fig.3.
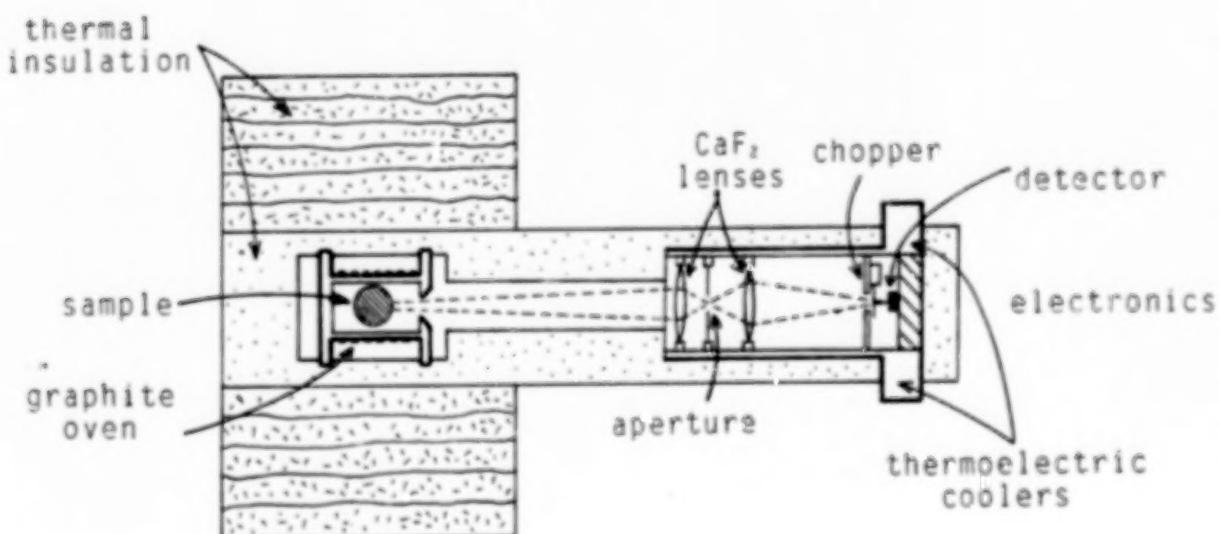

Figure 3. Schematic diagram of alloy solidification experiment.

The test device consists of an oven that contains the sample, an infrared -non-contact- temperature detector, and the control electronics. Grafite was chosen as the oven material due to its thermal

4

characteristics and ease of machining. To avoid wetting of the walls by the melted sample, an inside cover of boron nitride was provided.

The heating element is a resistance heater which surrounds the oven's outside surface. The thermal insulation for the oven consists of a Maranite structure. The temperature of the alloy is measured by using an infrared detector and maintained within predetermined values by the controller. The temperature of the oven is measured by using a thermocouple. The melting point of the alloy is 480 degrees C. This temperature will be exceeded by approximately 40 C and allowed to cool at a precise rate to approximately 50 C.

Vacuum Measurement Experiment

Vacuum measurements are conducted with a cold cathode tube, in view of its linear response, from 10E-3 to 10E-7 Torr., and its drift-free long-term stability; it is also resistant to atmospheric pressure operation. The tube is powered by 12Vdc from the battery pack, that is fed to a DC/AC converter with a 127Vac output. The sensor requires 1.5KV that is obtained from a transformer, and produces a 10mV output signal which is preamplified before relaying it to the data memory. The power source for this experiment is capable of delivering 160W-hrs and is diode protected; a maximum of 200A at 200W may be obtained in extreme conditions from this lead-acid power pack.

The purpose of this experiment is to determine vacuum pressures at different times during flight, including the variations that result from a change in attitude of the shuttle. Pressures inside of a chamber in the GAS/CAN that is venting through the battery purge ports and a filter are not well known yet; however, this information is of considerable importance in many of our future experiments, and may be of interest to other researchers using the STS.

In normal operating conditions, the measurements from the cold cathode are used by the vapor deposition experiment to trigger some of its key events, otherwise it is collecting data continuously until its power source runs out. Several additional advantages of the vacuum gage are that the sensor has no filament that can burn or break, and it may withstand up to 400 degrees C without damage; it also presents the advantage that it will not sputter; it is constructed of aluminium and is designed such that electrical leakage is prevented by the presence of insulation between cathode and anode. It is also equipped with a solid state controller that can be turned off from various ports in the microcomputer which can, in turn, be programmed in advace to start or to stop its functions.

EXPERIMENTAL SEQUENCE

Once in orbit and with the proper switches active, the microcomputer starts a supervision routine in order to establish the condition of all components, in particular the energy sources. The first experiment to start operations is the vapor deposition. The controller allows for a current to flow to the basket, one at a time, and starts the substrate heater, leaving some time in between for

battery recuperation. Simultaneously, measurements of vacuum pressures are being recorded for use in earth-bound validation experiments.

The alloy solidification experiment starts some time later after the first is completed and has its own power source. The sequence of events is as follows: a) all components are supervised for normal preoperational values, b) the heating coil is fed with a controlled current, whose values were determined in ground tests, c) the thermocouples are activated, following the temperature rise until it reaches 100 degrees C, at which time the IR detector is turned on to control the heaters (ref 3 describes this detector in detail). During this time temperature data is stored, whilst also used for active-adaptive control. When the temperature reaches the desired values, cooling begins at a predetermined rate, one of the key parameters of this experiment. In the case of a failure in the IR detector, backup thermocouples would monitor and provide the necessary control data to the controller. After the sample, as established by the detector, has lowered its temperature to about 60 C, the experiment is considered complete.

During most of the flight, temperatures are being recorded in about 15 test stations distributed over the entire canister. This activity is mostly of use for supervision of overall temperatures in the case of an uncontrolled situation, in order to stop all power to heaters, but it is of considerable value in the validation of thermal models of the canister, that will be tested also in the ground. The design of aerospace equipment, and its life cycle is directly propor-tional to power management thus, thermal models, however inaccurate, must be developed to gain practice in the operation of such devices, for which theoretical models are rather limited in practice. This is specially true in the case of satellites which occupy presently our attention.

EXPECTED RESULTS

From the thin film evaporation activities we expect to study space grown samples with several techniques, among them electron microscopy, both transmission and scanning, to determine the size distribution and crystallography of island formation and coalescence processes. It is also of importance to study the defect structure and density, since several previous microgravity experiments report, see for example ref. 4,5, different growth rates and defect density. Surface studies by means of Esca analysis is also planned, to clarify the structural growth nearby impurities. We expect these results to be useful in microelectronic manufacture and design.

The solidification experiment has also a multirole benefit, mainly in the clarification of microstructural formation in an impurity deter-mined solidification. Previous studies in superplastic alloys found that the phase mixture is related to behaviour at high temperatures, particularly with respect to strength loss and corrosion resistance, up to this point, everyone agrees that something is occuring at the micro-structural level, but few offer a plausible explanation. This experi-ment will produce a sample that presents a structure with nucleation

starting at the impurities, and with a growth pattern that suffered little transport effects in the abscence of convection; also, stresses that remain embedded in the structure due to crucible contractions will be totally abscent; thus, the microstructure of this particular sample will be studied in great detail, by means of the above methods, together with additional techniques such as x-ray microdiffraction, Moessbauer spectroscopy, and mechanical properties evaluation.

CONCLUSIONS

This first scientific-technological experiefce in direct space research has been already of valuel despite.the fact that our equipment rests at the Cape. The reasons are quite varied; they start with the experience gained by a group of engineers and physicists in a field considered, even in this day and age, as a luxury for a developing country. The spinoffs have produced already various solutions of interest to industry and other research projects, even before the experiments are spaceborne; in particular, we can mention the IR detector, the controller, which at present we develop further, and the use of new materials to solve old problems.

These activities have also generated other interests, as mentioned above. Our incursion into satellite technology is focusing on several projects such as a data collect/dump satellite, a remote sensing experimental satellite, and an ultraviolet all-sky survey satellite, some in combination with resources from other developed and developing countries. Finally, we see this type of work slowly gaining support from other institutions in the country, and because of a future increase in payload-to-orbit transit, we perceive a future of highly motivating work.

ACKNOWLEDGEMENTS

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GET AWAY SPECIAL EXPERIMENTER'S SYMPOSIUM
OCTOBER 27-28, 1987
GODDARD SPACE FLIGHT CENTER

PROJECT EXPLORER, GAS #007
STS-61C, COLUMBIA FLIGHT

MARCE DATA EVALUATION

BY

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ABSTRACT

The GAS #007 Project Explorer Experiment data recorded and radio downlinked by the Marshall Amateur Radio Club Experiment (MARCE), the first Get Away Special radio experiment, are compared and evaluated.

A compatability assessment, of the student experiments and the MARCE power, control and data systems, during the STS-61C Columbia flight in January 1986 is presented. Analysis of the GAS container's thermal environment, located near the center of the GAS Bridge is discussed.

BACKGROUND

GAS #007, here after called G #007, was sponsored by the Alabama Space and Rocket Center, Huntsville, Alabama and the Alabama/Mississippi section of the American Institute of Aeronautics and Astronautics (AIAA). The MARCE design, development, testing, coordination, volunteers, support and flight history are described in the GAS Experimenter's Symposium Proceedings[1,2,3]. The G#007 measurements consisted of six temperatures, one each main battery voltage and current and the container pressure. Eight status conditions were stored in the MARCE memory as well as downlinked (DL) by amateur radio, however, the status data was intended for information only. All of the DL data, received from the world wide amateur radio groundstations, has been converted to engineering units, formatted and plotted. The on-board stored memory data was more difficult to reduce and took much longer. This on-board data has now been converted to engineering units, formatted and plotted and analysis is nearly completed. This paper documents the assessment of the flight results.

EXPERIMENT MEASUREMENTS

G #007 consisted of three student experiments and MARCE. Experiment #1, Solidification of Alloys, contained two Ovens. Oven #1 housed Lead (30%)/Antimony, requiring 400° C for melting. Oven #2 contained Copper /Aluminum (4.5%), requiring 700° C for melting. MARCE measurements T1, for Oven #1 and T2, for Oven #2 were assigned

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as overtemperature measurements and for safety controls, whenever Exp. #1 was operating. T1 and T2 settings were designed to give an off-scale reading of 20° C, unless higher temperatures were encountered. The 700° C, in Oven #2, caused the temperature to rise to 38° C on the oven's external surface, as shown in Figure 3. Oven #1, at 400° C, resulted in the external surface to reach only 18° C. T1 then is a straight line at 20° C.

Exp. #2, Plant Physiology, contained MARCE measurement T3 to trace the seed/root growth chamber temperature. The main battery powered the 2.8 watt heater unit, located around the inside of the well insulated package. T3 was for measurement only, no control. A thermostat was set to actuate at $+17^O$ C, whenever G #007 power was applied.

Exp. #3 contained a 6 ml, 0.3 M solution of potassium tetracyonaplatinate, for crystal growth. MARCE measurement T4 was set inside the insulated growth chamber. Six "D" cells powered the 2.7 watt heater. The thermostat was set to activate at $+10^O$ C, to conserve power.

Exp. #4, MARCE, contained the remaining measurements, which were important to all experiments. T5 measured the internal container thermal environment. It was attached to the outside case of the 28 VDC to 7.5 VDC converter. T6, the battery internal temperature measurement, was installed by Eagle Picher, the Solid Rocket Booster (SRB) battery manufacturer. Thermister T6 was designed for measuring 0° C to 60° C and was located in the potting near the center of the battery, which provided good thermal conduction. Chris Rupp[4] designed a safety control and temperature monitor circuit for the battery thermister. The safety control circuit fed GAS malfunction circuit #2. V1 was the SRB battery voltage measurement and I1 was the SRB battery current measurement. P1 measured the one-atmosphere Gaseous Nitrogen container pressure.

DATA STORAGE AND DOWNLINKS

MARCE stored the nine measurements and the eight status conditions, at the start of every 10 minutes. The MARCE memory did not store the Exp. #1 data, since the Exp. #1 data system was designed to collect and store all of it's own data. The second and third radio downlinks (DLs), during Exp. #1 operations, contained the eight Exp. #1 temperatures (4 for each oven), central daylight time and five status conditions. The radio transmissions, at the start of each minute, during the second and third DLs, provided excellent near real time data, for operational performance assessment of all experiments and G #007 housekeeping.

During the three 8-hour DLs, 1440 data messages were transmitted from Columbia, of which 485 (34%) were recorded by groundstations. The audio cassette recordings, received by the Marshall Amateur Radio Club (MARC) were verified. The MARCE memory stored 144 data messages during the 24 hours of downlinks. The results show that 341 more messages were received in the DLs than were stored in the MARCE memory, during the three radio DLs. 327 of the 485 DL messages were available, at MARC, before the flight package arrived in Huntsville, on February 5, 1986. The added DL messages allowed a significant number of data points, more than the MARCE memory provided. Major experiment operations were scheduled during the second and third 8-hour DLs. The added DL messages revealed near real time experiment operations and housekeeping status, that were not available from the on-board memory.

POWER SYSTEM ASSESSMENT

The power consumed by G #007 was near 37 ampere hours, for the 110 hours and 20 minute power-on time, giving more than 26% reserve. Included is the unscheduled 8-hour DL, which consumed 2.52 AHr. Without the added 8-hour DL, the power reserve would have been more than 33%. The battery voltage V1, in Figure 1, shows no degrading, with time. The extremely low temperatures, plotted in Figure 2, likewise do not degrade the V1 voltage level, during any part of the mission. The I1 current levels were as expected for the various loads. The reserve is based on the specified 50 AHr capacity. The SRB batteries

10

have shown capacities of up to 65 AHr, at 28 VDC. More battery power was available, since the software and computer "cut-off" was set at 22 VDC. This indicates that much more heater power was available and added heater units should have been installed, for cold contingencies. STS-61C was an extra cold mission, as indicated by Figure 2. No lower than -5° C was expected.

G #007 power was turned "OFF" by the Columbia crew at 3:19:31:09, (D:H:M:S) STS-61C Mission Elapsed Time (MET), and 079:31:09, H:M:S, (G #007 MET), on January 15, 1986. The purpose was to prepare Columbia for a landing at KSC, on January 16, 1986, before an impending storm would hit KSC. However, due to bad weather the next morning, Columbia received a mission extension.

G #007 was turned "ON", for a second time at 4:05:14 (STS-61C MET), 079:40 (G #007 MET), on January 16, 1986, after a G #007 power "OFF" of 9 hours and 43 minutes. The transmitter was to be turned "ON" for DL #4, but Relay B was not activated, as shown by I1, in Figure 1.

The second G #007 power "ON" lasted for 13 hours, when the G #007 power was turned "OFF" at 4:18:14 (STS-61C MET), 092:40 (G #007 MET), for Columbia's expected landing at KSC. The next day, the mission was extended again, for weather.

G #007 power was turned back "ON" for a third time at 5:00:47 (STS-61C MET), 092:50 (G #007 MET). DL #5 did occur, as shown by I1, in Figure 1. The third G #007 power "ON" lasted for 17 hours and 18 minutes, when G #007 power was finally turned "OFF" at 5:18:25 (STS-61C MET), 110:20 (G #007 MET), for the landing of Columbia at KSC, on January 18, 1986 at 6:59 a.m. CST, after a 6 day, 2 hour, 4 minute mission (146 hours, 4 minutes), of which G#007 power was "ON" 110 hours and 20 minutes.

DATA AND CONTROL SYSTEM ASSESSMENT

All MARCE measurements, software controls, relays and the data system performed as planned, during the STS-61C flight[4]. Likewise, all three student experiments responded to the MARCE controls as planned.

The thermister calibation was verified during the G #007 thermal test. Strip chart recorders monitored the total testing of both the hot and the cold development/qualification testing. A laboratory thermometer, with external readout, provided the temperature calibration readings for the test chamber environment. Prior to the cold test, a 4 hour dwell at 0° C, stabilized the system. The test started with 24 hours at 0° C, followed by 8 hours at -5° C, during which time the Exp. #1, Oven #2 was operated. Next was 12 hours at -10° C, 12 hours at -15° C, followed by a 12 hour excursion to 0° C.

The hot test was preceeded by 0° C dwell for 4 hours. The test consisted of 8 hours at 20° C, 8 hours at 35° C and 8 hours at 45° C, during which time Oven #1 was operated. This was followed by 4 hours at 22° C.

The cold temperature (-15° C) revealed that added heater capacity was required. Heater capacities were increased three-fold in both Exp. #2 and #3. The transmitter was operated at the start of every 4 minutes.

The data and control system and all measurements operated as planned, during the hot and cold testing. The Digitalker[TM] output was plugged into a cassette recorder and activated by the transmitter "ON" signal, during the thermal tests.

The DL data and the thermal test data showed excellent correlation. The thermisters were all space qualified and proven reliable and repeatable. The pressure sensor (P1), used in the Space Processing Applications Rocket Project (SPAR) flights, proved to be reliable.

The control and sequencing, of the experiments, by the crew and by the microprocessor, during the mission, operated as planned, as did the six relays. The low gravity experimentation, during the crew sleep periods proved to be optimum. The Linear Triaxial Accelerometer measurements made by the Material Science Laboratory-2 (MSL-2), on STS-61C, showed that the quitest of each 24 hour day was during the crew sleep periods.

COLUMBIA ORBIT ATTITUDES ASSESSMENT

According to the STS-61C "AS FLOWN" attitude timelines, G #007 "power-on" was applied at 0:11:50 (day:hour:minute), STS-61C (MET).

Columbia had completed the IMU maneuver and was in Inertial Hold (IH). 30 minutes later, Columbia was put in the Solar Inertial (+YSI), Nose South Pole attitude and remained in the +YSI attitude for 10 hours, or through the rest of the 8-hour DL. At 0:18:53 STS-61C MET, 007:10 (G #007 MET), the radio relay from MARCE to the AMSAT OSCAR (AO-10) satellite and down to Guam Island was completed. Joel, KG6DX, recorded the relayed voice message. This was the first Amateur Radio relay (TDRS mode) in the GAS program and in Amateur Radio Communications. It is apparent that this secondary objective of MARCE would not have been possible, if the Columbia cold APU problem had not occurred.

The second 8-hour DL started at 1:07:55 and ended at 1:15:54, Columbia MET, at the nominal IH of 0° Pitch, 270° Yaw and 180° Roll (-ZLV Nose North).

The third 8-hour downlink started at 2:06:42 Columbia MET. The IH attitude of 21.80^o Pitch, 332.01^o Yaw and 180° Roll held until 2:07:45, when the IMU Pair C2 event changed the Columbia attitude to 283.00^o Pitch, 76° Yaw and 50° Roll. At 2:08:08 MET, Columbia was changed to -ZLV Nose North, with 0° Pitch, 270° Yaw, and 180° Roll, Local Vertical Local Horizontal (LVLH), until the end of DL #3, at 2:14:41 Columbia MET.

The voice messages received in DL #1: 46 of 480 sent; DL #2: 174 of 480 sent; and DL#3: 265 of 480 sent indicates that the best Orbiter attitudes, for ground station reception may have occurred during DL #2 and DL #3.

Figure 2 reveals that the Orbiter attitude has the predominate influence on the container thermal environment, with experiment power having significant thermal control. The only constant temperature period shown is between 70 and 80 hours. This was prior to the first landing attempt and just prior to the first G #007 "power-off".

GAS BRIDGE THERMAL ENVIRONMENT

G #007 forward position, near the center of the GAS Bridge, was requested for minimum interference to other (than GAS) payloads and for an optimum radiation pattern from the MARCE antenna. During a normal earth facing mission, this location would appear to provide a reasonably moderate thermal environment. Comparing a longeron-sill location with the center of the bridge indicates a warmer temperature on the aft sill, based on Orbiter and GAS Development Flight Instrumentation temperature measurements.[5] The abnormal flight attitudes of STS-61C and the thermal isolation, near the center of the bridge, are apparent reasons for the colder than expected temperatures (See Figure 2) measured on G #007.

The Chemglaze white surface, on the non-insulated G #007 Lid has an alpha/epsilon ratio of 0.4 compared to 0.1 for Silverized Teflon. The Chemglaze could provide a temperature rise of about 180° F compared to the Silverized Teflon, with a one Solar Constant input. Since the payload bay did not face the sun, such a temperature rise did not occur. Instead, the +YSI attitude caused an unexpected cold environment, during DL #1, as shown in Figure 2.

During the 8-hour DL #1, Exp. #2, #3 and #4 contributed 16 Watts. When the transmitter is not ON, Exp. #2, #3 and #4 contributed 6.8 Watts. A comparison of Figures 1 and 2 shows that power contributed by the experiments had little thermal influence, when Orbiter attitude points away from the earth and the sun.

During the DLs #2 and #3, Exp. #1 contributes 75 Watts, for about 18 minutes (Oven heat-up), followed by a 30 minute regulation using 45 Watts. For the remainder of the six

hours, a 15 Watt load provides heat for the canister. During all other times that the transmitter and Exp. #1 are not "ON", 6.8 Watts is the load.

The only time that the thermostat cycled on Exp. #2 was immediately following DL #2, as shown in Figure 2. This is apparently due to the combination of heat from Oven #2, Exp. #4 transmitter system, a favorable Columbia attitude and Exp. #2 heater. Figure 3 shows that the Oven #2 external surface heat-up (T2) occurs prior to the highest temperatures reached, in the G #007 container. The SRB battery temperature, shown in Figure 2 (T6), was colder than the other experiment assemblies, during the warm part of the cycles. T6 shows the thermal lag of the battery. This is apparently due to the large battery mass of 45 pounds.

SUMMARY AND CONCLUSIONS

The excellent operation of the MARCE power, data, instrumentation and measuring systems and the DL data provided the MARC team with a basis to assess the experiments performance. Strip heaters should have been installed around the inside walls of the insulation, in each experiment chamber. Exp. #3 should have been better insulated and should have used the main power (SRB battery). These changes could have made a significant difference in the operation of Exp. #2 and #3. Exp. #3 solution would probably not have frozen and a more conducive environment would have been realized for the root growth system in Exp. #2. Pressure P1 responded to the temperature changes, as shown in Figure 2.

A graphic example of GAS container thermal variations, with changes in Exp. power, is shown in Figure 2. During DLs #2, #3 and #5, T5 rises faster than T3, T4 and T6. T5 is mounted on the DC to DC converter, which has it's heaviest load during downlinks. Exp. #2, with the only operational heater, shows by T3, the dramatic drop with no heater power. All temperatures rose when power was reapplied. T6 saturated at -9.8 $^\circ$ C, due to the SRB battery thermister design for measuring no lower than 0° C. Container location, especially on the GAS bridge, requires special thermal considerations.

The GAS #007 MARCE temperature measurements reveal that heaters are required for experiments that are sensitive to cold temperatures. Special insulating measures are necessary, including the GAS lid, assembly mounting isolators, and the inside of each assembly.

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STS-61C GAS #007 MARCE MEMORY DATA

BATTERY VOLTAGE V1 (volts)

BATTERY CURRENT I1 (amperes)

GAS #007 MET - HOURS

FIGURE 1

14
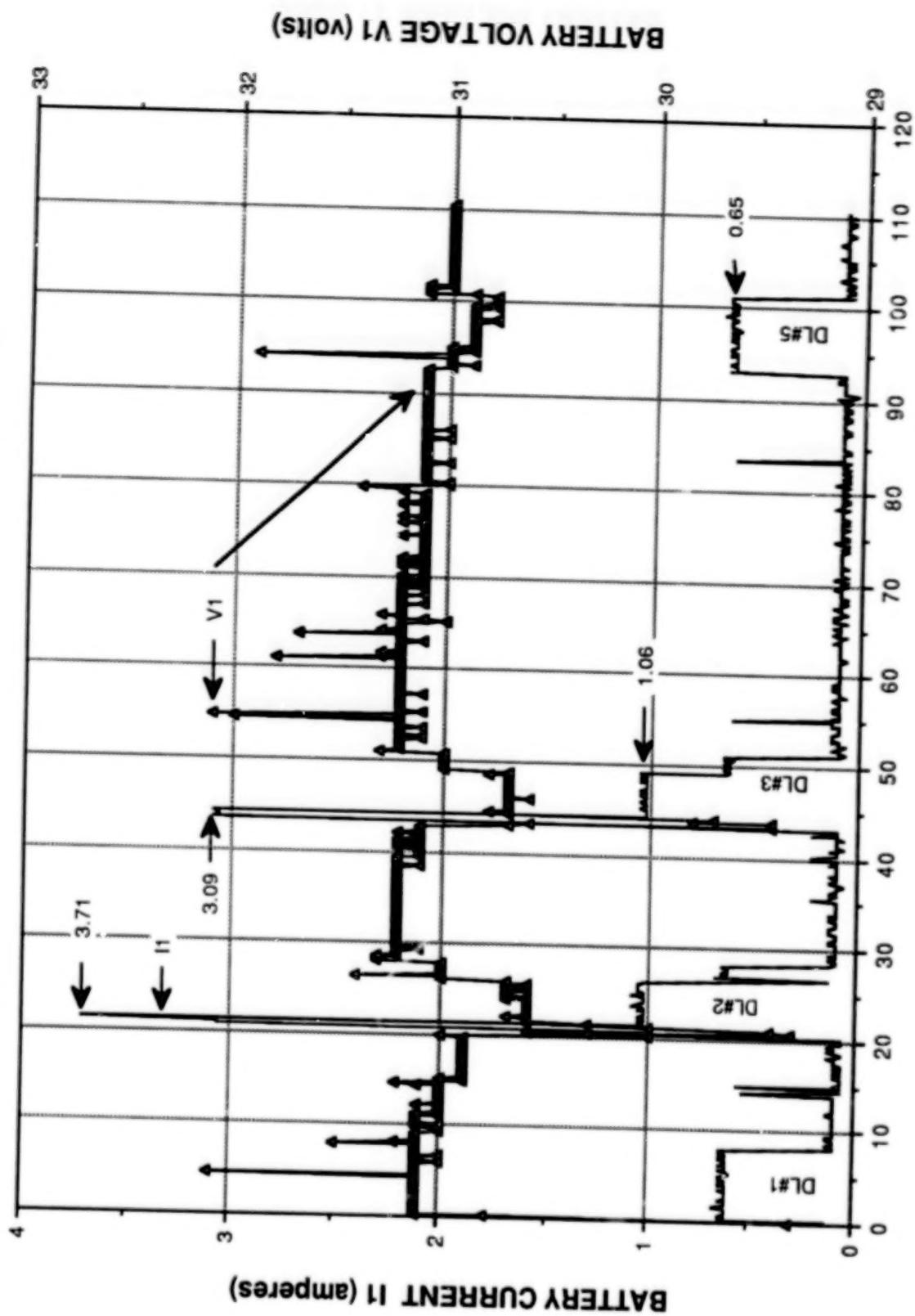
STS-61C GAS #007 MARCE MEMORY DATA

GAS #007 MET - HOURS
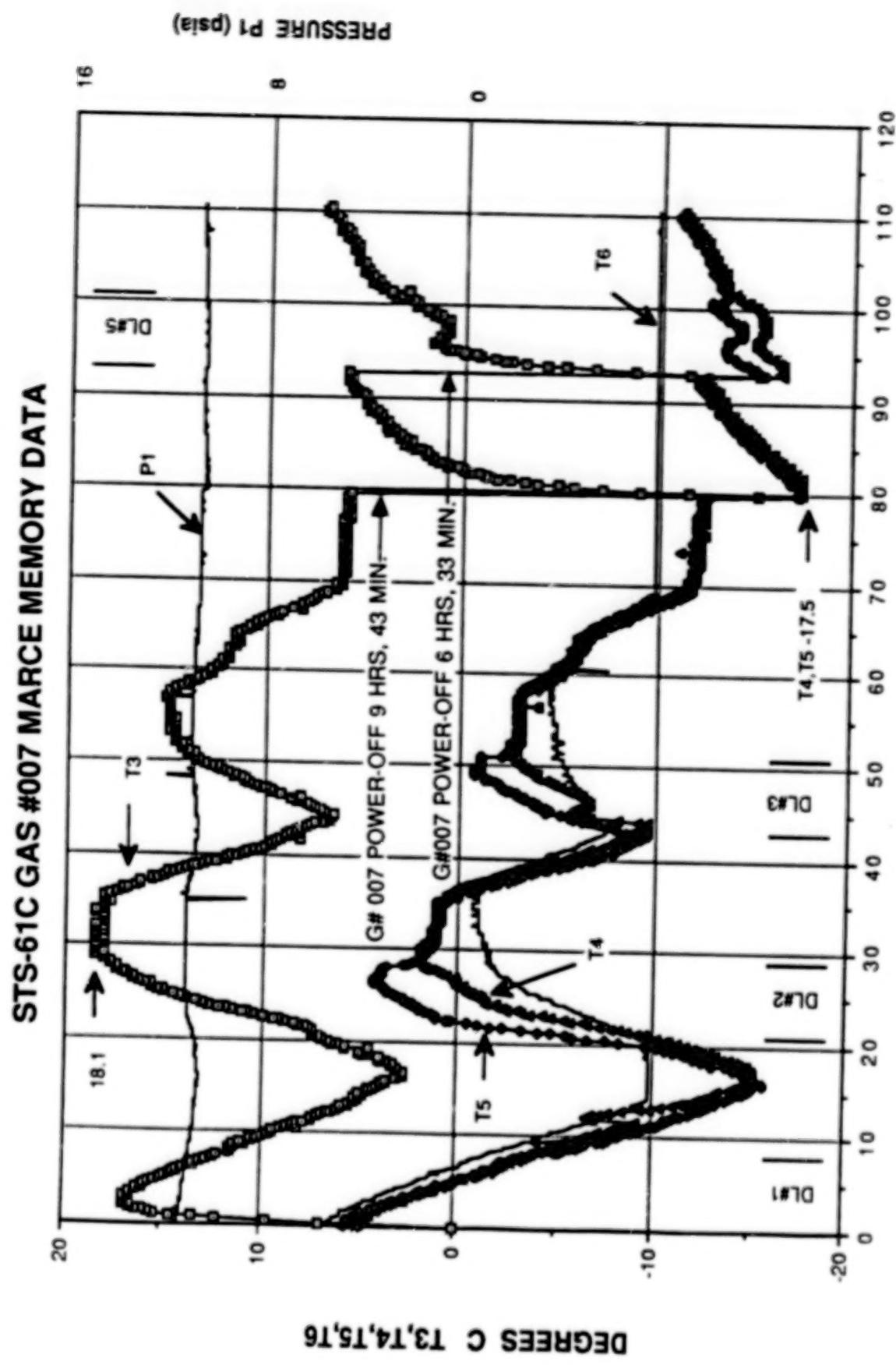
FIGURE 2

STS-61C GAS #007 MARCE MEMORY DATA

DEGREES C T2

CURRENT I1 (amperes)

GAS #007 MET - HOURS

FIGURE 3

16
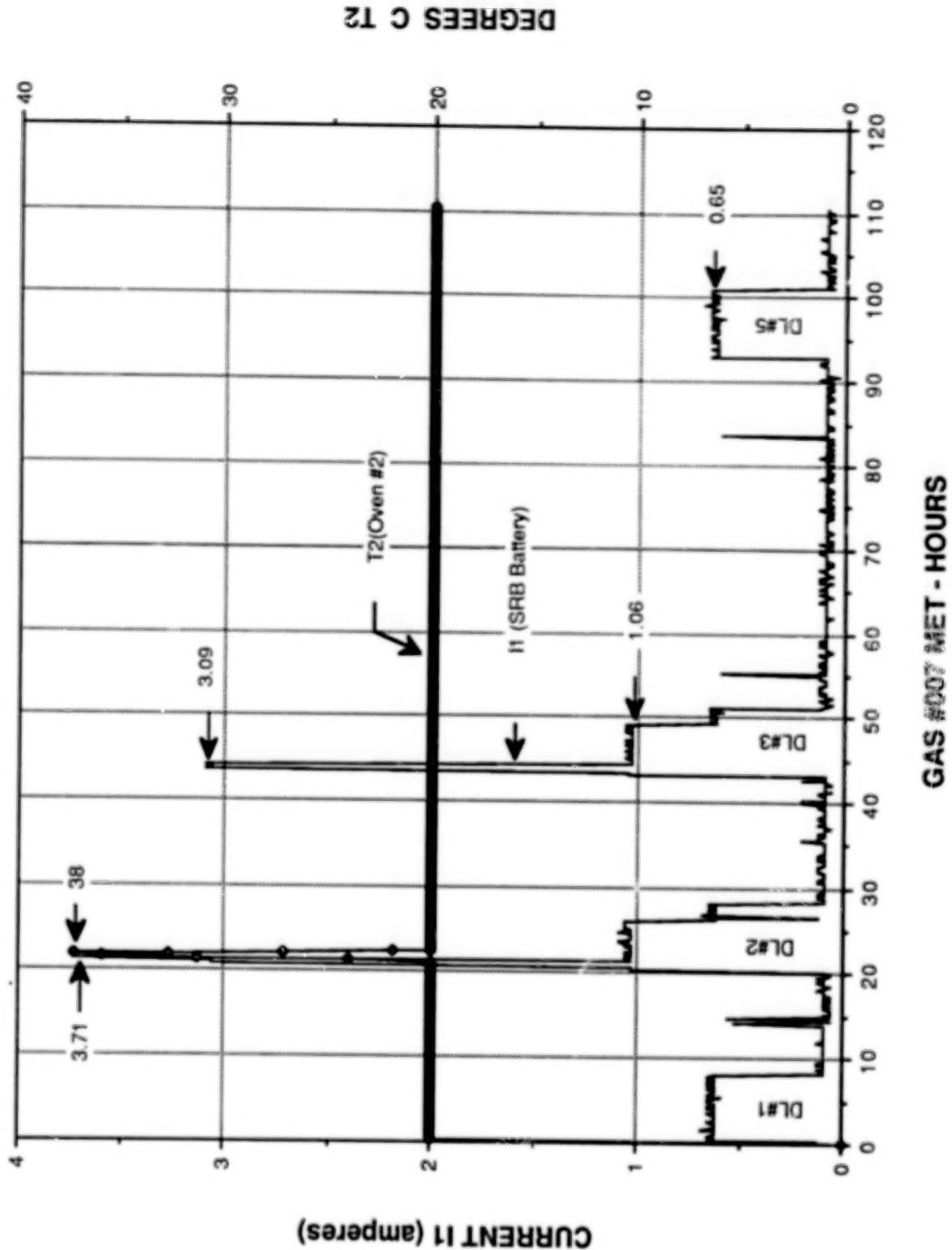
LASER INVESTIGATIONS FOR PAYLOAD G-652
PRIOR TO FILING PRE-FLIGHT ACCOMMODATION REQUIREMENTS

Joseph Bellina, M.D. Ph.D. & M.C. Muckerheide

ABSTRACT

In anticipation of presenting the pre-flight accommodations requirements to NASA for approval, we are investigating the physics, biology, electronic and chemistry aspects of laser experiments which are most advantageous to our flight.

Preliminary laboratory evaluation has been targeted with the realization that future flights of the shuttle may begin in 1988. It is our consensus that during the holding time before the resumption of flights, there is an extra margin of perfection which is possible and that the period prior to flight is working to our advantage technologically.

The problems that can be encountered in space flown laser systems are addressed and the analysis of data is offered as a model for pre-flight accommodation requirement filing.

Scientific investigation and invention are closely related and dependent upon each other. The age old saying that necessity is the mother of invention is often true. However, the inventions of today are also dependent upon many of the scientific building blocks of the past.

When working on the cutting edge of technology there are almost always constraints in developing new inventions. When working in space the constraints are often greater due to the harshness of the environment.

In great measure we are dependent upon those who have gone before us when it comes to experimentation and the development of new devices.

Because of new developments in the field of science which occur continually, it is essential to investigate the finest options before producing a system for space flight. In reviewing the latest technology and inventions we have arrived at the conclusion that, although get away special experimentation on board the Space Shuttle has been delayed during the past year, we have indeed had time to re-think our experiments and also apply the most recent concepts which can make our experiments more meaningful.

Before submitting our pre-flight accommodation requirements (PAR) package to NASA we have found it necessary to review by experiment the feasibility of the research.

To get the greatest advantage from the financial investment it is essential to select members for the payload team that have the necessary background.

In our particular payload GAS-652 we have addressed the needs of the scientific and administrative segments by selecting payload members that can optimize both disciplines. Figure I is a photo of our payload group.

FIG I
Payload Team
From left to right seated: Michael Petry, Mary McClutchy
From left to right standing: Reginald Sprecher, Rich Sportiello, Darrel Seeley, Mark Theiler.

Because so much depends upon proper scientific and administrative decisions in making the payload a success we have given the team a hands on responsibility from the beginning, and have addressed the many parameters essential in orientation around the experimenters handbook and the safety manual. Because our payload must also address the laser safety issue we have spent considerable time stressing the latter.

We have attempted ionization related experiments relative to concepts involving the Free electron laser and investigated magnetic field attenuation in plasmas.

Tests of high peak power neodymium laser have been orientated around the concept of producing the well known laser generated electrical breakdown for implementation in an environment for the production of amino acids. Stanley Miller conducted experiments using electrodes and electric sparks[1]. Our experiments will be conducted in microgravity using the spark from laser generated breakdown.
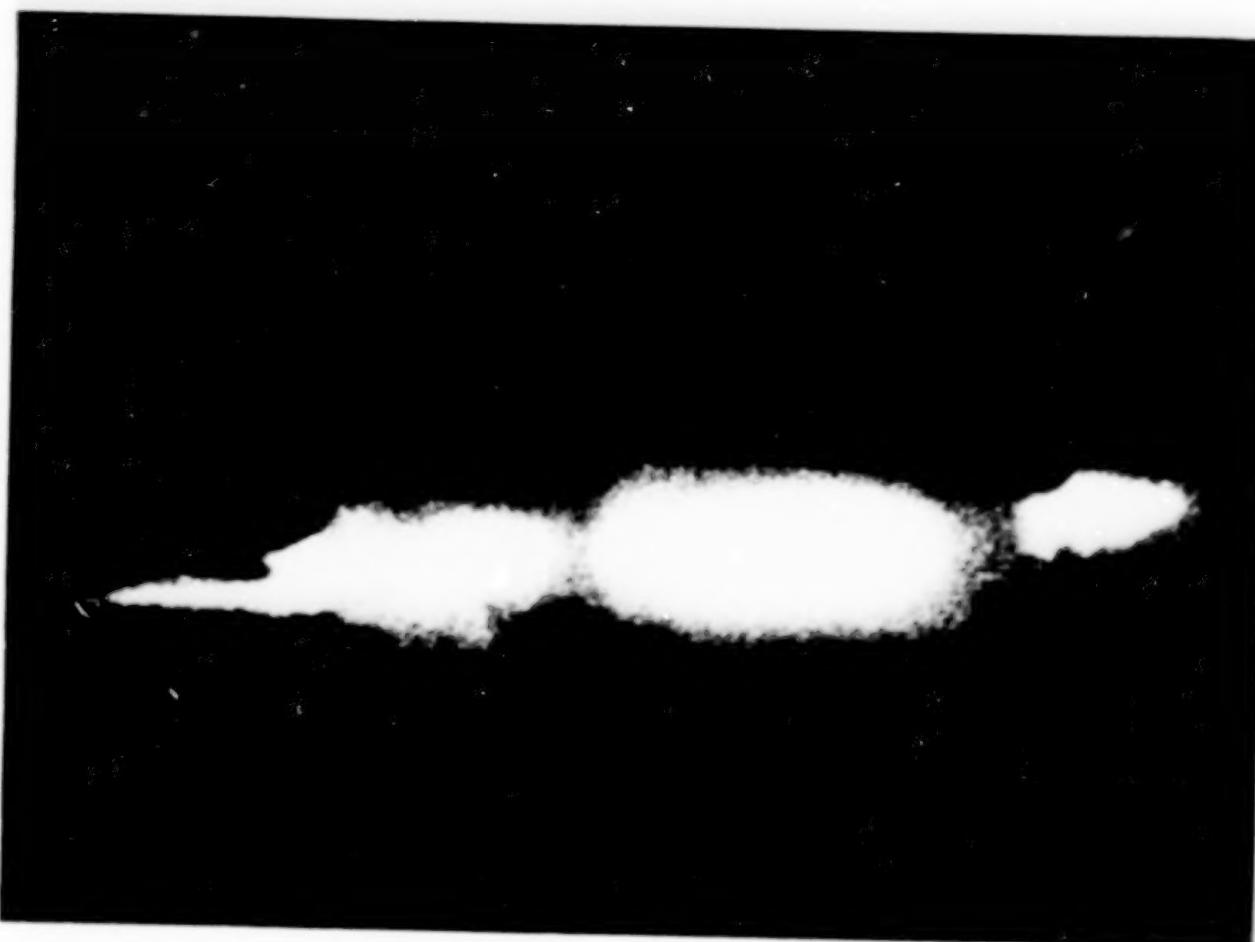

Figure II

Laser generated air breakdown for application in producing organic compounds (amino acids) from chemicals believed to have been present in early earth atmosphere.

Investigation of Free electron laser operation using the ram glow concepts[2-8] of the space shuttle included a search of the literature and magnetic attenuation of plasma in the laboratory.

Combinations of DNA and RNA in the focus of the neodymium laser are being investigated and relationships that may be essential in the combinants are being attempted before arriving at a distinct methodology for implementation in our PAR.

The problems that can be encountered in space flown laser systems are many. The problems we are mainly concerned with regard optics, temperature, vibration (lift off and landing), electrical supply, timing of on/off sequences, Q-switching techniques, and electronic noise rejection and safety.

The selection of an adequate laser system and electronics that do not easily lend themselves to latch up are being investigated. Hardening of the circuits and a review of previous information supplied in past GAS experiment symposiums offers a large amount of data for pre PAR development.

Our main emphasis in flying GAS-652 is on exploring the possibility of flying an orbital system although the methodology has not been determined.

Our payload concepts are embodied in our preliminary logo (Figure 3) and are graphically self-evident.

SUMMARY

We wish to address the following:

1. Investigation of physics, biology, electronic, and chemical aspects of the laser experiments. Before we arrive at a model we consider to be optimal for our payload we are doing proof of principle investigations.
2. Evaluation of scientific data is possible in this period of down time for flying in the GAS program and gives us the added option of learning more about past payloads and arriving at proper conclusions.
3. Our team is dependent upon many sources of information and continues to work energetically in developing an optimal PAR.
4. Our laser data analysis tends to lead us in the direction of using existing laser systems that have been space tested or innovations around new concepts such as those involving Free Electron Laser wigglers .
5. Our PAR will be based upon criteria which meet the latest safety specifications of NASA, with enough room for flexibility, so that adjustments can be made for operational capabilities.

ACKNOWLEDGEMENTS

Figure III
Preliminary logo for project

We believe that the logo (FIG III) we are presently considering does indeed
portray our greatest hopes for the flight of payload G-652.

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MATERIALS PROCESSING IN SPACE:
An Introduction to the G-480 Payload

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Payload Manager

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27 October 1987

ABSTRACT

The Space Research and Development Organization (SRDO) at San Jose State University has designed and developed a small self-contained payload (designated G-480 by NASA) which will perform four materials science experiments in low-Earth orbit aboard the Space Shuttle. These experiments can be categorized under two areas of investigation - corrosion and electrodeposition. While none of these experiments have previously been performed in space, both government and industry have expressed great interest in these and related areas of materials processing and engineering. Immediately following a brief history of the G-480 project development, this paper will provide a description of each experiment followed by a tour of the G-480 payload. Expected results will also be discussed along with the function, design and operation of the payload hardware and software.

HISTORY

In May of 1983, San Jose State University (SJSU) received a donation of flight costs for a Get-Away Special (GAS) Payload from Aero-Auto Industries of Sunnyvale, California. This marked the beginning of SJSU's involvement in NASA's GAS Program and, in turn, the first GAS payload to be developed in Northern California. In January 1985, students representing the Schools of Engineering and Science gathered under the directorship of Dr. Robert N. Anderson of the Materials Engineering Department to develop a payload concept. By July of that same year, a Payload Accoomodations Requirement (PAR) had been submitted and signed by NASA. This followed two reiterations in which assistance was given by the GAS Project Office at Goddard Space Flight Center (GSFC) resulting in the timely development of a PAR which was concise and to the point.

By August of 1985, a preliminary Safety Data Package (SDP I) was drafted and submitted to NASA. The SDP I review identified that many possible hazards existed, most of which were attributable to a lack of information rather than to safety considerations. It became evident to us that, whereas the PAR represented a brief description of the payload concept and requirements, the SDP required specific detail on every aspect of the payload design and operation as well as ground operations supporting the flight activities. By the time the Final Safety Data Package (SDP II) was submitted in April 1986, the number of

hazards were reduced and qualified. Currently, SRDO is involved in the final phase of its engineering and safety analyses known as "Phase Three" (SDP III) review with NASA; and nearing the payload hardware production phase. Extensive ground testing will commence early next year (1988) during which time the payload controller software will be debugged and experiment systems will be evaluated. G-480 Payload testing and integration will continue until the reactivation of regular STS flight activities.

EXPERIMENTS

BACKGROUND

I am often entertained by the looks I get from people who inquire about the types of experiments which we have selected to be flown in space. Often their reaction is that of surprise because they somehow expected something more than just electroplating and corroding objects in space. Although electrodeposition (or electroplating) is a very common industrial process and corrosion is a very common natural phenomena, both provide very interesting possibilities for space experiments. Unfortunately, many are simply accustomed to an 'Earthly' perspective of things. This is understandable since most of us are native of this planet and expect things to be consistent everywhere else. Of course, we all know this isn't always the case because the exceptions are often well worth examining. It is easy to be trapped in a train of thought where we limit ourselves in terms of our 'Earthly' environment and, unconsciously, we include variables such as gravity ($9.8m/sec^2$), the presence of air, orientation (up and down), thermal conductivity and many other things common to our environment. With the dawn of the space age, however, this can no longer be the case. GAS experimenters, in particular, need to discipline themselves with regard to these conditions. Such was the learning process that our organization encountered in the early days of its GAS project.

Prior to selecting our experiments, it was necessary to learn all that we could about the environment in which we would be operating. While we use the generic term 'space' to name the operating environment (anything above 50 nautical miles), it is more accurate to say low-Earth orbit (LEO). In fact, the Space Shuttle will never really leave the Earth's atmosphere. The Orbiter typically flies from 120 to 400 nautical miles in altitude which is confined within a layer of the atmosphere referred to as the ionosphere which is more so a dirty vacuum than air as we know it. One very interesting aspect is the presence of trace elements of oxygen in the ionosphere which will be discussed later on in this paper.

Fundamental problems regarding thermal flow and electromagnetic interference (EMI) were also noted. Lessons were learned involving the influence of gravity and that the term 0g is technically inaccurate (although still used generically to mean microgravity). As long as the Space Shuttle is orbiting the planet, it is still under the influence of gravity. While the Orbiter is in a constant state of free-fall, micro-gravity disturbances are generated through the use of maneuvering systems combined with other activities such as the motion of astronauts about the flight and mid-decks. All these things considered, our view of so called 'common' processes becomes quite interesting.

MATERIALS SPACE EXPOSURE TEST (MSET)

The largest and most visible of the G-480 experiments is the Materials Space Exposure Test (MSET). It consists of an Exposure Drum mounted in the window area of the GAS Motorized Door Assembly (MDA). This particular experiment is passive in the sense that it requires no other controls or initialization other than simply opening the MDA once on orbit. Operations in space have shown that ambient atomic oxygen

presents a troublesome environment for organic, graphite and metallic surfaces. This has resulted in structural degradation and changes in thermal characteristics, reflectivity and conductivity. These changes are caused by high energy impact and chemical reactivity due to absorption of gaseous atoms on material surfaces. A sampling of select materials including various common metals, alloys, thin films and substrates will be flown in the configuration shown in Figure 1. Additionally, some materials will be galvanically coupled to examine the rate of corrosion between two dissimilar metals.
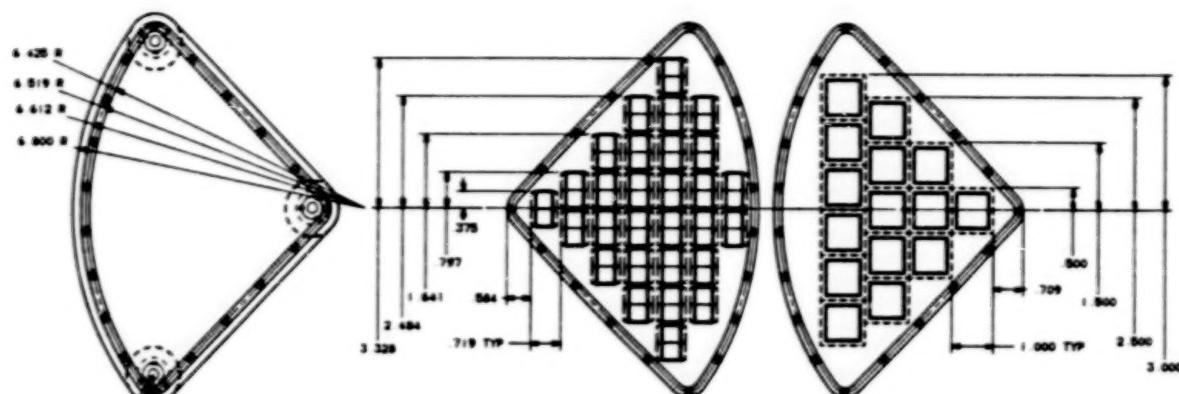
FIGURE 1

ELECTRODEPOSITION

The microgravity environment of space allows us to test electroplating techiques under conditions that are expected to produce unique physical, bonding and plating characteristics. Two experiments will test the effects of free-floating hydrogen molecules, produced during the plating process, on the structural matrices formed during low and high current density transfer of ions.

In the case involvng high current density plating, the quality of the plate is rather poor when performed on Earth. This process is often used in the production of powdered metals whereas ions, which are transferred from anode to cathode at a very high rate, fail to bond. When these ions adhere to the surface of the cathode they bridge out - ion upon ion. Under 1g conditions (Earth) these bridges collapse and become powdered metals. In a microgravity environment, these bridges should continue to grow undisturbed; thus, resulting in a structural matrices which will eventually support and reinforce itself. The low current density plating experiment will provide valuable insight in the production of a high quality surface plate in a microgravity environment. Figure 2 illustrates the test cell configuration of both electroplating experiments - low and high current density (left to right) respectively. The helix and the cube are the cathodes in these systems.

FIGURE 2

25
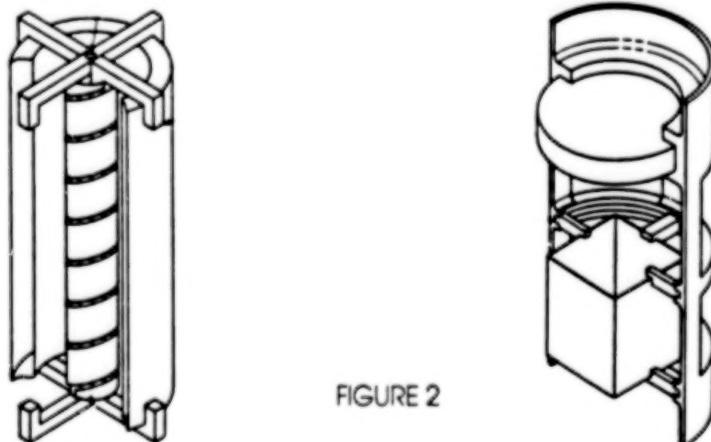
PITTING CORROSION

The formation of pits along the bottom, horizontal surfaces inside plumbing fixtures is attributed to the influence of gravity on sediments. These products build up and create a corrosive cap which initiates "pitting attack" or pitting corrosion. This experiment will examine the effects of induced pitting corrosion in a microgravity environment. The results of such tests have significant importance in design considerations of long-term space structures. Following the flight of G-480, the copper specimen used in this experiment will be cut and examined under a scanning electron microscope for pits and streaks. The ultimate goal in all of the pitting and exposure tests is to determine corrosion rates in microgravity environments. Figure 3 illustrates the development of pits on Earth and the configuration of the G-480 pitting specimen.
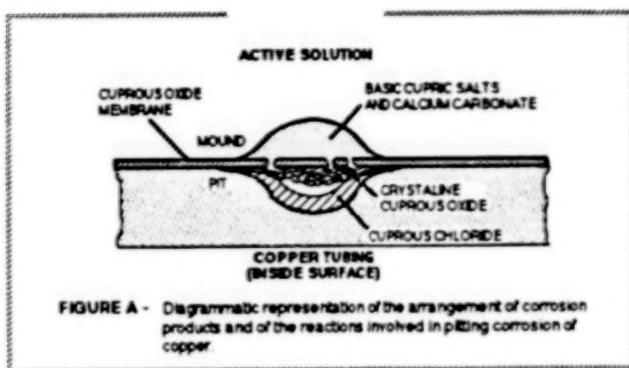
FIGURE 3

PAYLOAD

REQUIREMENTS

In addition to those requirements set forth by NASA, SRDO established further design specifications to improve the reliability and safety factors of the G-480 payload. A listing some of SRDO's design criteria are as follows:

1) All pressure vessels are contained within a secondary cell to provide a redundant level of protection in the event of leakage or cell burst.

2) Test cells are rated well above their expected pressures.

3) Prefer the use of space-qualified hardware.

4) The payload controller is programmed to monitor and control hazardous situations before they result in the shutdown of the entire system.

5) Thermal, electrical and EMI insulation.

6) All hardware has been designed to be reusable where possible.

7) Special emphasis on simplicity in design. Reduce the number of mechanical parts where possible.

8) Testing of all individual components and the entire G-480 payload system prior to launch.

9) Surface mounted hardware, such as the exposure drum, is designed so that all bolts, nuts and miscellaneous small parts are mounted from the underside of the drum (within the canister).

10) All nuts and bolts will be safety wired where possible.

11) Back-up power supply for the computer to prevent loss of data and/or excessive drain on primary battery pack.

FIGURE 4

THE G-480 PAYLOAD

27
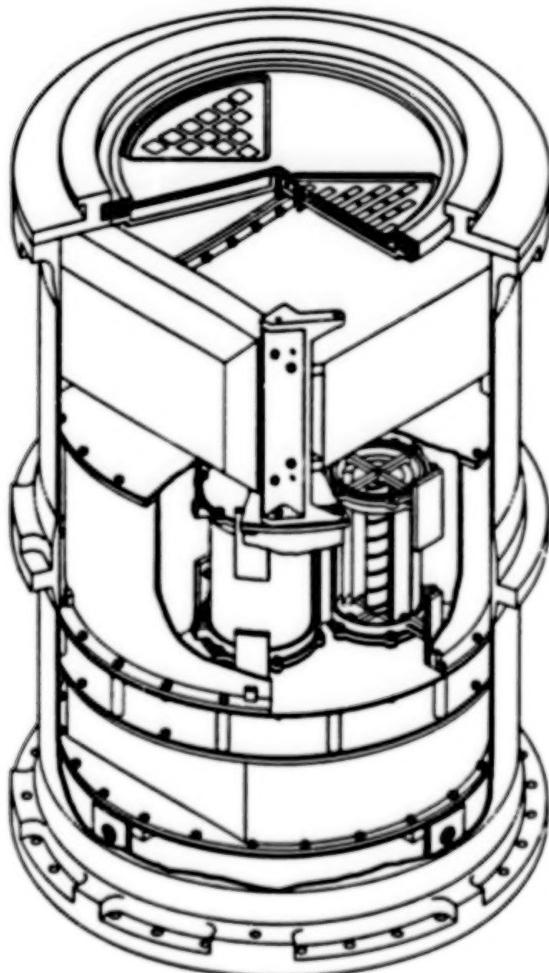
SPECIFICATIONS

As shown in Figure 4, the G-480 Payload will utilize the 5 cubic foot two hundred pound GAS canister with the Motorized Door Assembly option. By selecting to make use of the MDA, the overall payload weight becomes that much more critical due to a 40 pound penalty imposed with the use of the MDA. The following is a description of the G-480 Payload and refers to the cut-away drawing shown in Figure 4.

EXPOSURE DRUM

Atop the G-480 payload, mounted within the window area of the MDA and GAS endplate, is the Exposure Drum. Its most notable feature is the presence of two pie-shaped aperatures through which approximately 75 specimens will be exposed to the payload bay environment as part of MSET. Prior to the launch activities, the specimen trays are protected within the sealed exposure drum. As part of our final integration checklist, the specimen trays will be rotated into the aperature areas of the exposure drum at which time they will be protected by the sealed MDA.

POWER PLANT

Set between four structural post, which extend downward from the GAS endplate, is the battery box. It contains sixteen 25Amp-hour BC cell lead-acid batteries. Figure 5 illustrates the configuration of the left half of the battery box. The battery type and configuration are similar to that used in the AV-8 Harrier VTOL jet aircraft. Mounted to the battery box and between the two nearest structural posts is a switching power supply. This unit regulates all power requirements and contains a set of relays which will be used only in the event of pending emergency or as deemed necessary by the flight or ground crew.
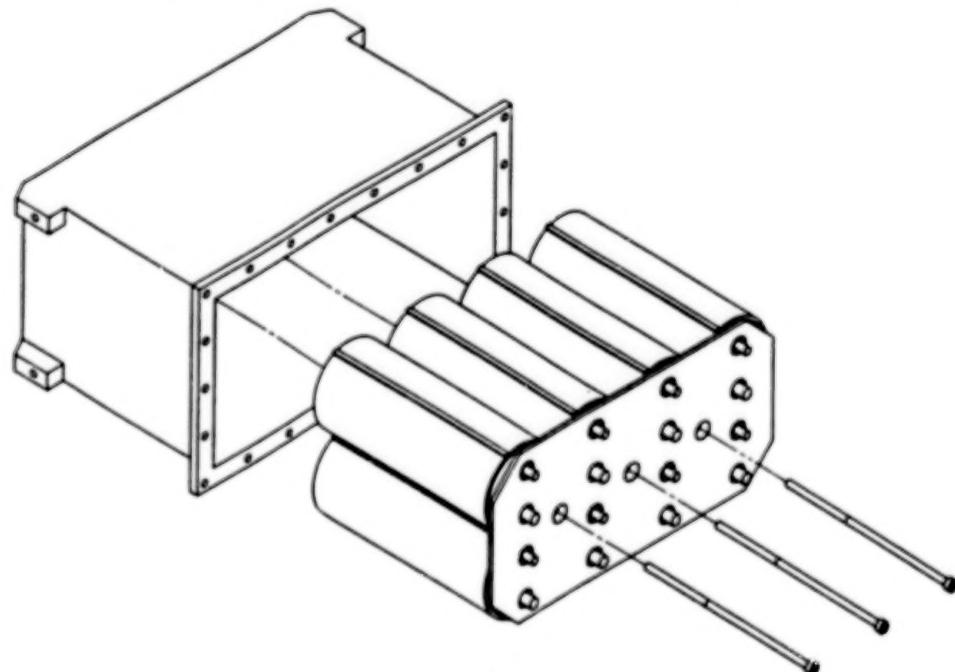
FIGURE 5

COMPONENT ENVELOPE

Centered in the G-480 Payload assembly is a large cylindrical container which we refer to as the Component Envelope. It contains all of the active experiments and serves as a secondary cell to limit

hazardous conditions that could develop such as leakage of test cells. The component envelope is divided in to three equal sized compartments, each of which is capable of being pressurized. Within each compartment is an experiment test cell (ETC) and an adjoining reservoir which will contain electrolyte solutions for each specific experiment. Centered within this component is a triangular cable bay which provides us with access to power (above) and control (below). Figure 6 shows a top view of the component envelope and the subassemblies for the pitting corrosion and eletroplating experiments.
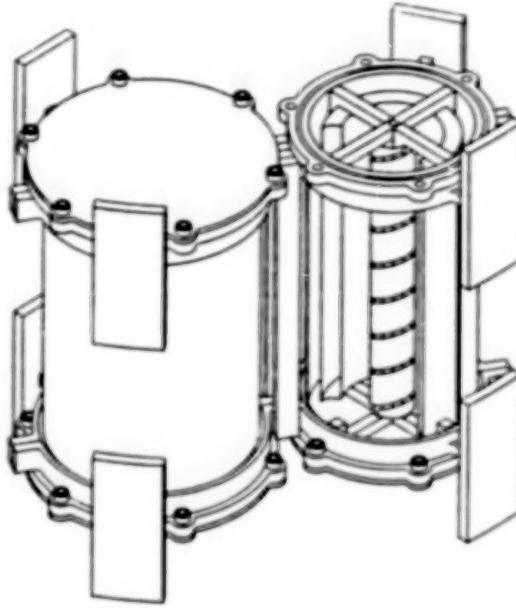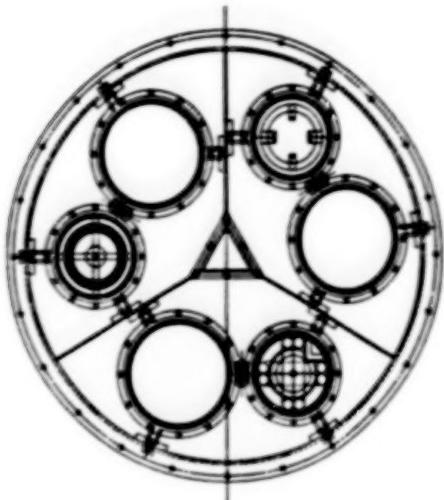
FIGURE 6

CONTROLLER ENVELOPE

At the base of the G-480 Payload is the Controller Envelope. This unit contains all data aquisition and control devices for the entire system. It is unique in that it also contains a battery back-up in the event of an unusually high discharge rate within the main payload battery system. This 16 bit payload controller consists of an 8086C processor (IBM compatible) and features: 1.2M bytes continuous memory, 192K bytes of ROM and a built-in clock. Originally designed for defense applications, this controller is very durable and has been tested for environmental conditions in excess of STS payload requirements. Software is currently in the early stages of development. We are evaluating several languages for use based on speed, reliability and programmer familiarity. The base of the payload is stabilized within the canister by four equally spaced lateral support bumpers.

OPERATIONS

Once the Space Shuttle has achieved orbit, the astronauts will activate relay A of the Autonomous Payload Controller (APC) resulting in the activation of G-480 and the opening of the MDA. The payload is programmed to begin house-keeping duties while preparing the experiments for operation. Shortly thereafter, the pitting corrosion experiment will be initiated. At a later time, just before a scheduled sleep period, the astronauts will activate relay B. This will initiate the electroplating experiments following a 1 to 2 hour wait. We do this because of past mission data which indicates that the least amount of microgravity disturbances take place during astronaut sleep periods. The deactivation of Relay B will indicate that the crew is preparing to complete inflight operations and return to Earth. All electroplating will cease and an inhibiting solution will be injected into the active pitting corrosion solution in order to slow down the corrosive process. The payload controller will then begin to shutdown each experiment, save the final data entries and prepare itself for reentry (i.e. the data storage unit has a retractable head). The deactivation of relay A will power down the G-480 Payload and close the MDA; thus, sealing the specimen materials involved in the exposure test until they can be examined in the lab.

CONCLUSION

It has been nearly three years now since we initiated the development of the G-480 Payload. We have done so with a core group of 5 people and many temporaries (those who work for about a semester or so). Most of us are full time students who have full or part time jobs on the side which only goes to show that GAS projects aren't just for professionals who dedicate the bulk of their time to a single program. Nonetheless, we have accomplished quite a bit and the benefits have been very rewarding. Local aerospace companies consider this to be one of the finest training experiences for those students who will go to work for them in the space industry. Many of the practical lessons have been learned here regarding the value of weight reduction and power conservation.

Whereas we were once pressed for ideas and payload concepts, we now have three on the 'back burner' and more under development. This progressiveness is not unique only to SRDO; other university programs and user group are experiencing the same influx of ideas because their people are now familiar with the GAS program, the Space Shuttle, and more importantly, its operating environment.

Of course, for those users who are just now getting started, a word of advise - be patient. We now enjoy a tremendous amount of support at the University level and in local industry involvement. This, needless to say, took a lot of work. Facilities are traditionally the hardest to aquire. Funding and staffing are also common headaches. The best vehicle, however, in realizing all these valuable things is to carry on with the paperwork. File your PAR and work your SDP through as far as you can take it. Eventually, you'll be holding the plans, signed paperwork from NASA and know what you're talking about when you approach companies and institutions. It really is not that difficult. In most cases, aerospace and other high tech companies have programs which promote such student activities. Ask not and receive not.

No one can be certain as to the results which our experiments may yield in space, nor the significance of the results. Perhaps this in itself is the most exciting aspect of Get-Away Special involvement. There are many opportunities to conduct experiments, both simple and complex, in space and do so for the first time ever. As more and more users make use of this vehicle that NASA has made available to us, I am certain that we will begin to see many more exciting developments and discoveries in time.

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TEN PAST AND TEN FUTURE GAS/MAUS-PAYLOADS

Abstract

MAUS - a German acronym for materials science autonomous experiments - is one out of a series of flight opportunities which the Space Program of the Federal Republic of Germany offers to scientists from the disciplines of materials research and processing for performing materials science investgations under micro-gravity conditions. Up to now ten MAUS experiments were flown which were dealing with the following scientific topics: decomposition of binary alloys with miscibility gap in the liquid state, interaction of a solidification front with dispersed particles, critical marangoni number, investigation of the magnetic compound MnBi, shrinkage of gas bubbles in glas melts and slip casting.

The ten future experiments are partly reflights with modification of the scientific objectives as well as new experiments in the fields of chemical reactions, heat-transfer, glass technology and Ostwald-ripening.

Looking to ten flown payloads the peculiarities of instrument technology in GAS-cans and its evolution will be discussed with emphasis on structure, electronics and thermal design. A typical modern payload using 100 % of the resources will be presented.

1. Programmatic aspects of the MAUS-Project

In 1979 the German Minister for Research and Technology (BMFT) signed 25 GAS-LSA's and established the MAUS-GAS program. The MAUS-project management was assigned to the German Aerospace Research Establishment (DFVLR), and MBB/ERNO was selected as the industrial prime contractor. The programmatic concept of the project is based on 2 missions a year of dual MAUS-payloads in the GAS-program. To achieve this goal the MAUS-standard-system has been developed. To assure the feasibility of a multitude of materials science experiments the design of this system was based on the requirements profiles of 25 experiments. With the provision of 10 flight units of the MAUS-standard-system the possibility for accomodation of different experiment specific hardware designed by the experimenters themselves is given.

Scientific Objectives and Results

The ten experiments flown up to date within the MAUS Project cover a wide range of topics from the area of material sciences. Essential scientific results have been obtained which either stand on their own or serve as supportive data for Spacelab experiments. A listing of the experiment titles and the responsible Principal Investigators is given in Table 1.

Table 1: Summary of MAUS Payloads Flown

MAUS Mission	Payload No.	Shuttle Mission	Launch Date	Carrier	Experiment Title	Primary Investig.	Institution
1	1	STS-5	11/11/82	GAS	Verification Payload	Dr. Otto	DFVLR Köln
2	2	STS-7	06/14/83	SPAS-01	Critical Marangoni Number	Dr. Schwabe	U. Giessen
2	3			SPAS-01	Alloys of the System Zn-Bi I	Dipl-Ing Pant	Krupp FI Essen
3	4			OSTA-2	Solidification Front	Dr. Klein	DFVLR Köln
3	5			OSTA-2	Metallic Dispersions I	Dr. Otto	DFVLR Köln
3	6			OSTA-2	Metallic Dispersions II	Dr. Otto	DFVLR Köln
4	7	STS-11	02/01/84	SPAS-01A	Slip Casting I	Dr. Schweitzer	NTU München
4	8			SPAS-01A	Gas Bubbles in Glass Melts I	Prof. Frischat	U. Clausthal
5	9	STS-51G	06/17/85	GAS	Alloys of the System Zn-Bi II	Dipl-Ing Pant	Krupp FI Essen
5	10			GAS	Slip Casting II	Dr. Schweitzer	NTU München

Ten payloads for future flights in the Get Away Special Prgram are in various stages of preparation and a listing of the experiment titles and the resonsible Principal Investigators is given in Table 2. A condensed form of the scientific objectives follows below.

Table 2: Summary of MAUS Payloads in Preparation

MAUS Mission	Payload No.	Carrier	Experiment Title	Primary Investig.	Institution
6	11	GAS	Critical Marangoni Convection	Dr. Chun	Univ. Essen
6	12	GAS	Oscillatory Marangoni Convection	Dr. Schwabe	Univ. Giessen
7	13	GAS	Pool Boiling	Prof. Straub	Univ. München
7	14	GAS	Gas Bubbles in Glass Melts	Prof. Frischat	Univ. Clausthal
8	15	GAS	Ostwald Ripening	Dr. Ratke	MPI Stuttgart
8	16	GAS	Reaction Kinetics	Prof. Frischat	Univ. Clausthal
9	17	GAS	Chemical Instabilities	Dr. Bewersdorff Dr. Avnir	DFVLR Köln
9	18	GAS	CO_2 Dissolution in Glass Melts	Prof. Frischat	Univ. Clausthal
10	19, 20	GAS	Interconnected MAUS Payloads	TBD	TBD

Critical Marangoni Convection:

Marangoni convection in this experiment is achieved by a temperature gradient between two circular plates which can also be rotated. The following goals are considered: Documentation of the influence of iso-rotation on the steady and oscillatory Marangoni convection; evaluation of the shape stability of the floating zone configuration during rotation; determination of the influence of higher Marangoni numbers on the hydrodynamic stability of Marangoni convection by variation of the temperature gradient. Convection is made visible in silicone oil by dispersed particles. Observation is by a laser cut technique in a defined plane which is recorded by a movie camera.

Oscillatory Marangoni Convection:

The goal of is experiment is to investigate Marangoni convection and to determine the critical Marangoni number at which the convection becomes oscillatory. Oscillations (about 1 Hz) are observed by means of a thermo-couple within the liquid zone. The material to be investigated is $NaNO_3$. In addition to previous successful MAUS investigations the length of the column will be increased giving access to a different aspect ratio.

Pool Boiling:

Pool Boiling (nucleate boiling) and forced convection are the most effective heat transfer mechanisms. From the many fluid physics phenomena which are observed in boiling kinetic heat and mass transport by evaporation and condensation is independent of gravity. This experiment will lead to a physical separation of the gravity driven parameters and therefore to a better understanding of the boiling process. A platinum wire immersed in Freon 12 will be used to initiate boiling. The bubble behavior will be recorded simultaneously by two cameras with different recording frequencies.

Gas Bubbles in Glass Melts:

Fining is one of the most important processes on technical glass fabrication.The removal of gass bubbles from glass melts can be achieved in two ways: Rising of the bubbles controlled by buoyancy (which is not possible in microgravity) and dissulution by diffusion. The shrinking of a He-bubble at around 1100 ° C was successfully recorded in a previous MAUS experiment. This investigation will be performed at the higher temperature of 1300° C to complement data on the diffusion in a wider temperature range. The convectional influence is expected stronger and a larger difference between earth and space

experiment will result. In a follow-up experiment the objectives will be extended towards technically relevant glasses like the dissolution of CO_2 in silicate glass melts.

Ostwald Ripening:

The phenomenon of Ostwald ripening is represented in a dispersion by growth of larger droplets on the expense of smaller ones. For this kind of studies metallic alloys with a miscibility gap in the liquid state are well suited like the system aluminum-indium. Samples which are already in a dispersed state will be heated into the miscibility gap but not above. With a series of samples Ostwald ripening and related interfacial phenomena will be studied. The experiment will require furnaces with long-term temperature stability and a regulating accuracy of smaller than 1° C.

Reaction Kinetics in Glass Melts:

The interdiffusion between two silicate glasses (potassium and rubidium silicate) and the corrosion behavior of SiO_2 glass by alkali halogenide is observed. Transport mechanisms in glass melts will be derived and a theroretical model for this case defined. Disturbing buoyancy forces are avoided by microgravity conditions.

Chemical Instabilities:

The spontaneous formation of three-dimensional structures may occur in systems far from thermodynamic equilibrium. This process must involve transport of matter by convection and/or diffusion. To clarify the mechanism of pattern formation a space experiment will be performed to exclude gravity driven convection. The photochemical reaction will be activated by ultraviolet light in microgravity and pattern formation with its consecutive development photographed by an optical camera.

Interconnected MAUS Payloads:

In this MAUS 10 mission two containers will be interconnected to transfer data and electrical power. This feature is very important to meet the challenge of future advanced payloads. Preliminary studies in this direction have already been performed. However, the scientific experiments for these missions have not yet been selected.

3. Instrument Technology

The basic design of a MAUS-Payload consists of the standard
experiment mounting structure (EMS), the battery (Ag-Zn, Ni-Cd)
the standard electronics for experiment control and data
acquisition, the housekeeping system, and the experiment
hardware including experiment dedicated electronics. The past
10 MAUS-experiments have been flown with this standard
configuration, which has been presented in detail in former
GAS-Symposia. The experience gained during the past MAUS
missions showed that in connection with progress in technology
experiments supposed to be accomodated in the Spacelab could
well be flown as an outonomous payload in the GAS-program.
As an example of such a complex payload MAUS-payload DG-504
will be presented (Fig. 3.1). The experiment modification
needed to suit the requirements of that payload will be
discussed.
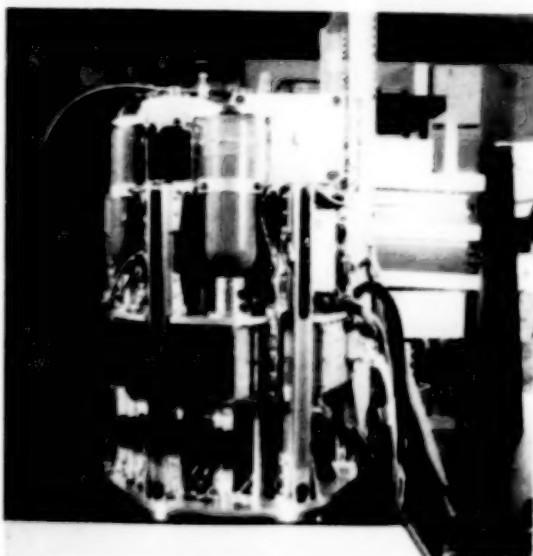
Fig. 3.1: MAUS-Payload DG 504
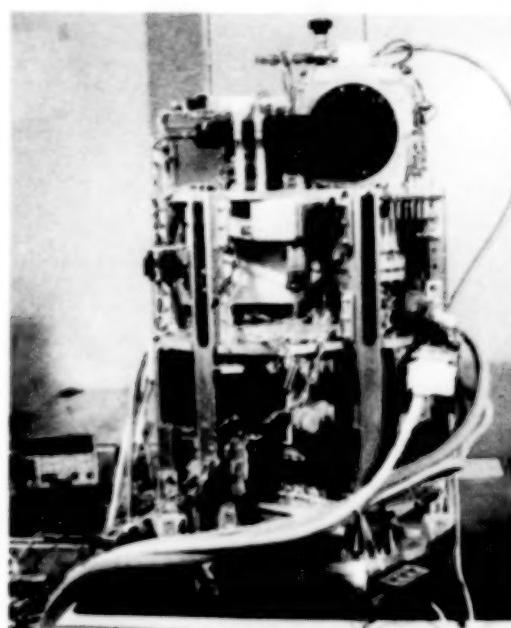
To reach the scientific goal, this payload requires the
following resources (the nominal ones of a standard
MAUS-payload are given in parenthesis):

o Mass: 42.2 kg (20 kg)
o Energy: 1.36 kWh (1.04 kWh Ag-Zn-battery with 46 cells
  instead of 80)
o Command: 26 (16)
o Data: 24 Mbit (10 Mbit)

The command and data requirements could be fulfilled using one analog output to generate 10 additions and by using thinner tapematerial and reducing tapespeed. The optimized experiment hardware without interface electronics requires almost the total volume available. Thus, the interface electronics could not be accommodated on the experiment platforms. The only solution was to construct a new adapter ring (Fig. 3.2) allowing the accommodation of an interface electronics box containing up to fourteen cassetts of experiment dedicated electronics.

The voltage regulators as well as the clock unit of MAUS experiment DG 504 could not be assembled in one cassette each, if conventional electronic components were used. Therefore, the units were partly manufactured by using SMD (Surface-Mounted-Device) technology resulting in a high packing density especially by applying multilayer techniques. Fig. 3.3 shows the voltage regulator unit.
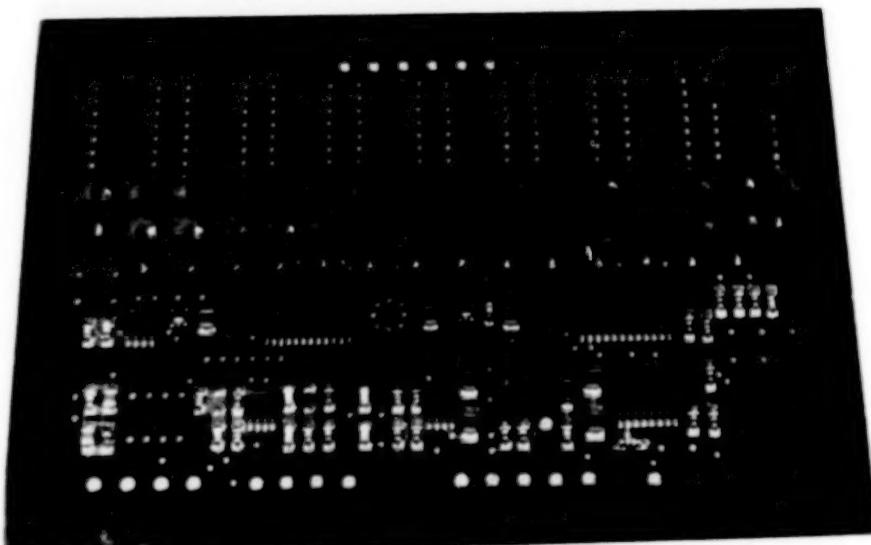
Fig. 3.2: Card with SMD's

Further advantages of SMD technology are:
- higher mechanical stability concerning vibration and shock
- parasitic capacities and inductivities are drastically
  reduced

Due to the accomodation of the interface electronics on the new adapter ring, the available space for the battery is reduced to almost 50 %. Consequently the mass available for experiment hardware increases of approximately 12 kg. Further mass reduction of the standard system is achieved by using a dc/dc converter to supply standard electronics as well as by reduction of structure mass, e.g. open spaces in platforms.

These modifications also lead to a reduction of the available energy to almost 50 %. But to perform a reasonable experiment from the scientific point of view 1.36 kWh are needed. The only solution is a change in battery type from Ag-Zn to $Li-SO_2$ non -rechargeable batteries, both produced by the company SILBER-KRAFT.

$Li-SO_2$ battery packages have already been manufactured according to the safety requirements of the STS-program (Fig.3.3). The advantages of these batteries are:

o almost unlimited lifetime (no problem with delays of
  STS-missions)
o safety features
   - reverse-save cells
   - diode-quat safety concept
   - temperature / current fuses

o compared to other battery system
   - low cost of cells
   - high energy / mass ratio
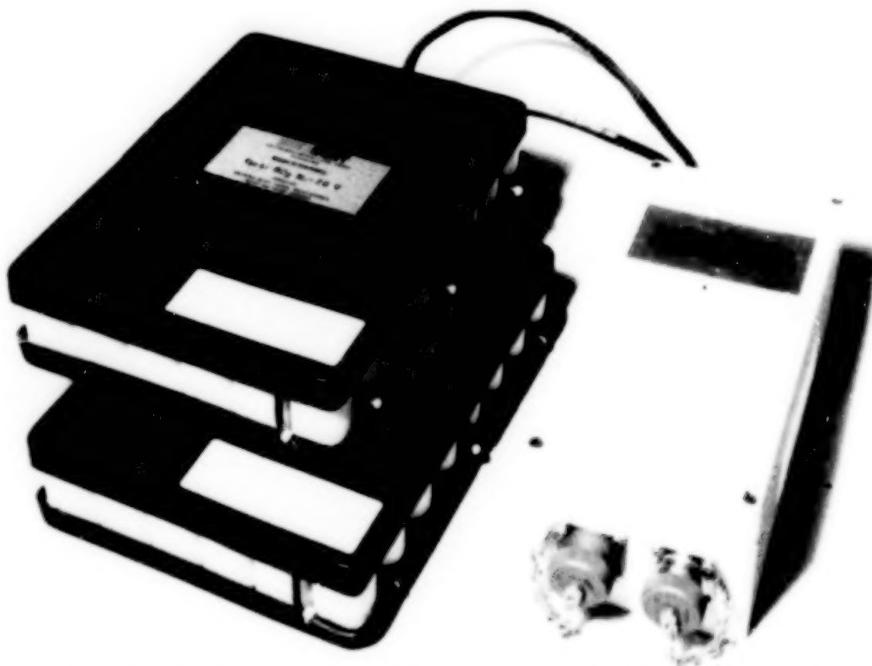
Fig. 3.3 Engineering Model of $Li-SO_2$ Battery Cell Packages together with the Distribution and Fuse Box.

Up to now, for each up MAUS-payload a thermal analysis has been
performed. In a mathematical node-model the thermal properties
were imitated. The optimal insulation can be calculated for
critical components.
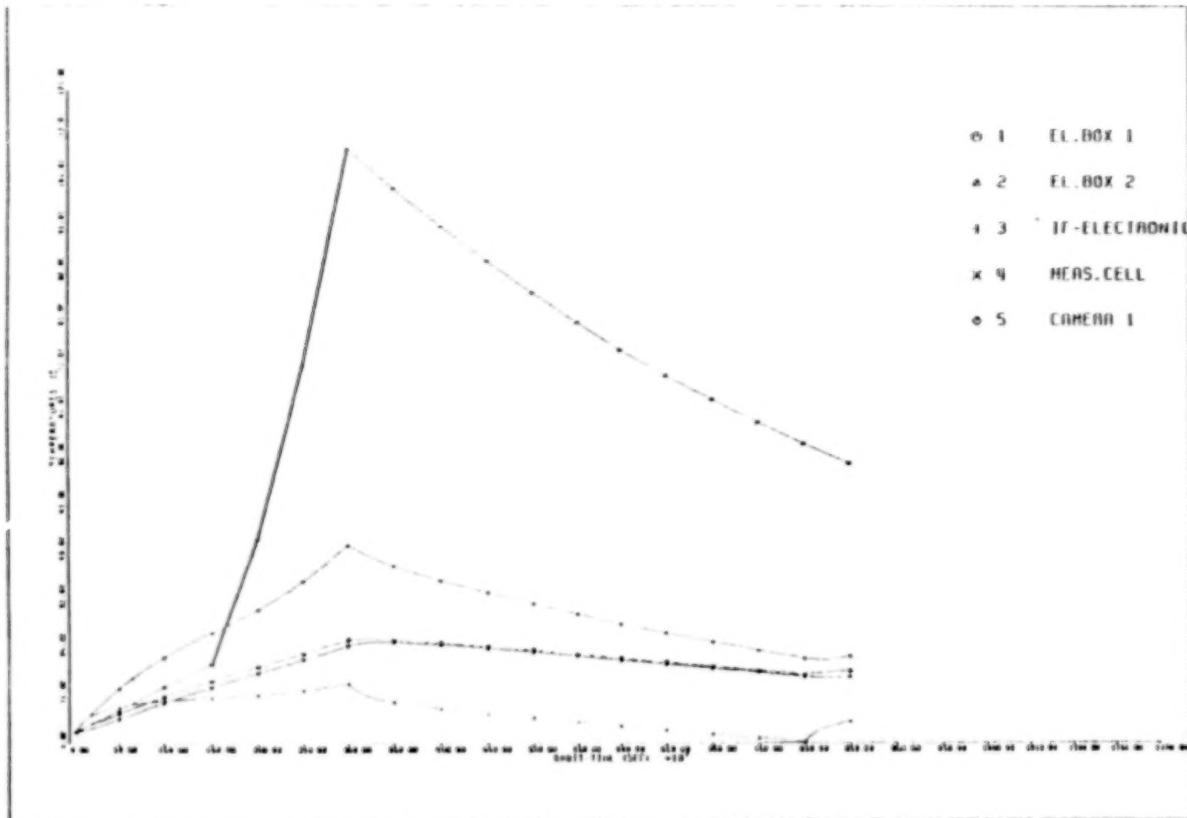
Fig. 3.4: Temperature vs Time, Experiment DG 504

From the ten flown MAUS-payload it turned out that a passive
thermal control system was sufficient to meet acceptable
temperature values.
MAUS payload DG 324 "Gas Bubbles in Glass Melts" will be
reflight of MAUS payload DG 318 but with a different experiment
profile (higher temperature, longer duration). With an average
power consumption of 300 W for 3.7 hours, the thermal analysis
showed that this experiment needs additional thermal equipment
to avoid overheating of hardware mounted in the vicinity of the
furnace.
Assuming the experiment mounting plate of the GAS-can to be
used as a radiator, the heat transport form the upper experi-
ment platform to the radiator has to be increased. A change of
the post material from V A-steel to aluminum turned out not to
be sufficient. Only the integration of heatpipes can provide
the required conductive heat path. The detailed layout of the
heat-pipes and further thermal analysis is currently under
development.

38

AN UPDATE TO THE MITRE/WPI SPACE SHUTTLE PROGRAM
GASCAN G-408

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ABSTRACT

The objective of the MITRE/WPI Space Shuttle Program was to develop a set of scientific meaningful experiments that could be flown in a Get Away Special Canister. Currently, the first GASCAN is finished (G-408) and ready to be launched. The program has been so successful that the design and development of a second set of experiments has been started (G-533). This paper will describe and summarize both of these programs.

I. INTRODUCTION

The MITRE/WPI Space Shuttle program was started in December of 1982. At that time, the objective was to have WPI engineering students develop a set of experiments that could be flown as a Get Away Special (GAS) payload during the 1985-86 academic year.

As with any complex program, we were overly optimistic and did not finish our first payload until late 1986. In addition, because of difficulties in performing a finite element analysis of the experiment support structure [4] and the submission of the required NASA safety documents, this payload has only recently been ready for space-flight.

The primary purpose of this paper is to describe certain aspects of our first payload. Because of the success of the first payload development program, we have started the development of a second set of experiments. Consequently, some details of these experiments will be provided. Finally, a brief overview of the organization of our joint university/industry program will be presented.

II. PROGRAM OVERVIEW

In December of 1982, the MITRE Corporation of Bedford MA and Worcester Polytechnic Institute (WPI) of Worcester MA entered into a cooperative agreement of joint sponsorship for the design and implementation of a Get Away Special Canister (GASCAN) payload. For MITRE the agreement was a logical follow-on to a variety of NASA related work conducted by the corporation for the past ten years. MITRE's aim was to use the project as a means to obtain first-hand knowledge and experience with NASA space operations and procedures. For WPI, it was an excellent opportunity to couple the college's project oriented educational philosophy to the real-world problems of system development [3].

The Major Qualifying Project

One of the unique aspects of

the WPI degree program that was particularly amenable to the development of this program was that each undergraduate student was required to successfully complete an intensive, year-long technical project [5]. This project, known as the Major Qualifying Project or simply MQP, typically encompasses four seven-week terms (one academic year).

The MQP was important to our decision to join in a cooperative development program because it was a key factor in the implementation of a multiyear program to develop the experiments. In addition, because of a significant number of prior MQPs that were supported and co-advised by industrial contacts, there was a mechanism in place to manage projects supported, in part, by industry. Thus, the WPI project environment was ideally suited to the Space Shuttle venture.

The multiyear program that was developed was based on a five term (one and one-quarter year) commitment by students and a multiyear commitment by faculty advisors. It was recognized early in the planning stages that the uniqueness of the experiments, the intended environment and the overall complexity of the experiment development process warranted a long-term commitment by both the advisors and students to ensure the program's success.

Project Groups

An average of 40 students a year, primarily representing the disciplines of electrical, mechanical and chemical engineering have been involved with experiment development. These students have generally been divided into teams with from two to six students and with one to three faculty advisors.

Approximately fifteen WPI faculty members and five MITRE engineers/scientists advise the projects on a regular basis. The advisors meet with their student team members 2-3 hours/week. Students are expected to spend approximately 17 hours/week on their project. Overall, the level of a student's activity is equivalent to one-third of a full academic load per term, for each of the four terms during their senior year.

Program Management

The management of the joint program has been in the hands of a Technical Steering Committee (TSC). This committee is composed of four WPI faculty and one or two MITRE engineers/managers. The responsibilities of this committee have been to insure that (a) the GAS canister was filled with experiments, (b) that the experiments were developed in a manner that would result in functional and reliable hardware, (c) that the experiments would comply with all applicable design, safety, scheduling and budgetary requirements and (d) that the experiments were scientifically significant. As with most committees, the day-to-day operations of the program, the generation of the required safety documents (PAR, PSDP, FSDP, P3SDP) and interactions with the GSFC technical liaison were the responsibility of the committee chairperson.

The general organization described above has worked extremely well during the development of our first set of

experiments (G-408). As a result, a new TSC has been formed and a new chairman appointed for the development of the second set of GAS experiments (G-533).

III. EXPERIMENT CHOICE

Scientifically, we have attempted to encourage the development of original experiments that have not previously been conducted in the space environment [2]. Although our funding is not commensurate with what one normally expects to spend for long-term space flight and/or complicated space flight experiments, we believe that each of the proposed experiments will provide unique scientific data or prove an original engineering concept.

An interesting aspect of all the experiments is the emphasis on integrating and understanding diverse systems from various fields representing the basic sciences. At a time when many students, particularly at the high school level, are minimizing their involvement in the basic sciences, it has been refreshing to have a program where the fundamental goals of each experiment are embodied in a good understanding of physics, chemistry and earth sciences.

IV. THE FIRST GASCAN (G-408)

Each of the experiments that are part of this package will be described. We will note both the status of the experiment, the concept we wish to test and, very briefly, how we intend to perform the test. Obviously, much more detailed information can be found elsewhere [1-4,6].

Film Sensitivity Experiment

This experiment will test for film fogging as a result of exposure to the radiation encountered during low Earth orbit. Small pieces of black-and-white film are sandwiched between thin, light blocking sheets of a composite material. An optical densitometer has been designed to evaluate the amount of fogging, if any, that occurs. The results from this experiment will have a direct impact on an experiment being developed for our second GASCAN.

Zeolite Crystal Growth Experiment

This experiment will determine whether a low acceleration level environment will promote the growth of large zeolite crystals in a small, heated reactor vessel. A liquid growth solution will be brought to the reaction temperature and stabilized at that temperature for three days. An electronic controller will maintain the required temperature, activating a heater coil wrapped around the autoclave when necessary. The entire unit is contained in a super insulated vacuum canister to minimize heat loss and power consumption.

This experiment is particularly intriguing since it was developed under the auspices of a faculty research project. Subsequent to the development of this experiment, the faculty advisors applied for and received funding to continue research on the growth of zeolite crystals in a low acceleration environment.

Fluid Behavior Experiment

Several methods for measuring the behavior of a two-phase fluid system in a low acceleration environment will be tested. Two identical measurement chambers

will be used; one containing a "wetting" solution, the other a "non-wetting" solution. The measurement techniques are based on a thermodynamic properties measurement system and an ultrasonic measurement system.

Micro-Gravity Accelerations Experiment

Three low-level $(10^{-4}G)$ accelerometers in a triaxial arrangement have been integrated with the appropriate instrumentation to capture low G accelerations. The data from this experiment will be recorded by the Environmental Data Acquisition System. It is believed that very low level accelerations experienced by experiments compromise the quality of experimental data for experiments that require exceptionally low environmental acceleration levels.

Environmental Data Acquisition System

This unit is not a formal experiment but rather a completely self-contained data acquisition system for storing data from other experiments and for cataloging the environment internal to the GASCAN from launch to landing. A barometric relay will activate the system during launch. During its operation, data will be stored from the Zeolite experiment, the Micro-Gravity Accelerometer experiment and the Fluid Behavior experiment. Data will also be stored from several temperature transducers, three high level accelerometers, gas pressure and sound pressure level transducers and the battery voltages. All data will be stored on digital cassette tape for post flight analysis.

Experiment Support Structure

Although not officially an experiment, a significant amount of effort went into the development of our Experiment Support Structure (ESS). The resulting structure was composed of a tri-wall frame with the battery pack in a hermetically sealed demountable box on one end and an end-plate holding several experiments on the other end.

During the summer of 1986, a Civil Engineering graduate student performed a complete finite element analysis on the structure to evaluate its overall strength and to determine the fundamental modes and frequencies of oscillation [4]. The ultimate margin of safety for the structure is 0.5 while the fundamental frequency of oscillation is 67 hertz, both well above the respective NASA specifications.

Testing

Probably the most important aspect of any GAS payload is the type of operational and environmental testing that was performed on the unit. We dedicated a significant amount of time to this task. Everything was tested, from individual boards and components to the full integrated system.

Testing included electrical and mechanical functional evaluations, cycle tests, environmental tests (-10 to +40°C), vibration tests (5 G_{rms} for five minutes), storage degradation tests and simulated integration -> storage -> launch -> recover tests. Although we encountered minor problems, there were no obvious areas where

reliability was a problem. Indeed, we are extremely confident that if the payload is properly installed in the flight GASCAN, it will function properly.

V. THE SECOND GASCAN (G-5\3)

Targeted Research Areas

As a result of our success with our first set of GAS experiments, we have decided to emphasize three similar research areas for our second GASCAN. These areas are fluids management, microgravity combustion and atmospheric science.

WPI has a strong research and professional basis for emphasizing these areas. For example, several Mechanical Engineering faculty members are nationally recognized experts in the area of fluid mechanics research concerned with modeling of fluid systems. This expertise stems from research at the Alden Hydraulics Research Laboratory, a well known physical modeling laboratory previously associated with WPI. Their general interests are in the area of the behavior of fluids under low and extremely low acceleration levels.

From a fire safety perspective, WPI has one of the only graduate departments in the nation in Fire Protection Engineering. The faculty members in this department are interested in issues related to fire initiation, detection, propagation and interdiction in an enclosed, low acceleration environment such as presented by the proposed Space Station. Obviously, a GASCAN presents an ideal mechanisms by which various

practical engineering aspects of the science of fire protection in a space station can be evaluated.

Faculty at WPI also have substantial expertise ir radio frequency propagation ₁n the atmosphere. This expertise has led to the development of an experiment wherein electromagnetic emissions from thunder storms will be monitored and used to trigger UV, IR and visible wavelength spectral recorders. The interest of the faculty is in establishing whether thunder storms strong enough to create wind shear hazards can be detected from orbit.

Regardless of the area of emphasis, our general goal with our second GASCAN is to integrate faculty sponsored research, graduate research and undergraduate senior project work into a cohesive and scientifically meritorious program for the development of space flight experiments. Ultimately, we believe that this type of organization will, like the Zeolite experiment described above, lead to further funding outside of the current program.

Combustion Experiment

The purpose of this experiments is to study how combustion occurs in a low acceleration environment. Several different types of combustible material will be ignited with a focused IR lamp. The gasses and particulate matter that are emitted by the material will be studied as the material begins to burn. This experiment will be particularly interesting to observe because the emitted substances will most likely not dissipate from the vicinity of

the host material in the low acceleration environment of the GASCAN.

Fluid Flow Experiment

Fluids in a low or zero acceleration environment will behave distinctly differently than those in a normal one-G environment because of the increased importance of surface tension. To study these differences as the effective gravity goes to zero, we have undertaken the development of a spinning platform that will be housed in a GASCAN. This platform will then be used to study the formation of vortices at acceleration levels from approximately 0.05 to 1.0 G. The platform being developed is being designed so that it can be used for a variety of fluid behavior studies over the course of many flights.

Micro-Gravity Accelerometer Experiment

From the results reported for earlier GASCAN experiments, it is clear that the cargo bay of the Space Shuttle is not a "zero-G" environment. Indeed, the results from some experiments seem to indicate that they were seriously compromised by the non-ideality of the "zero-G" environment. As a result, we are developing a very low level accelerometer to quantify the accelerations that are experienced during a typical GASCAN flight. This accelerometer will be able to sense accelerations on the order of 10^{-5}G.

Atmospheric Event Detector

Several students are interested in the detection of lightening and possible associated IR events during storms. As a result, these students are developing a multi-frequency, multiplexed RF receiver and various optical detection systems that will statistically quantify the occurrence of optical and RF "pulse like" events. The system will operate in two phases. During the first phase of operation, multi-spectral pulse data will be collected and statistically analyzed. During the second phase of experiment operation, events that are considered "statistically significant" will be recorded and photographic pictures will be taken on IR film. During post-flight data processing, the photographic images will be correlated with the recorded events and a profile of the types of multispectral events that can be expected to be encountered during low earth orbit will be developed.

Support Teams

In addition to the experiment teams, we have several students working on the development of a new support structure and a new end-plate. The structure will integrate the experiments, the rotating platform, all of the experiment electronic control systems and the power supply system. The new end-plate will have a window for taking photographic pictures and will have, in some fashion, an integrated antenna for the multispectral pulse detector experiment.

The major efforts of the support teams include the qualification and finite element analysis of the support structure and the safety qualification of the new end-plate.

VI. DISCUSSION

The MITRE/WPI Space Shuttle Program and the associated projects have represented an ambitious and complex undertaking that has required dedication by the students and staff alike. We believe that the educational, engineering and scientific benefits to the joint staffs, and particulary the students, have merited such an undertaking.

Although we are encouraged and delighted with the experiments we have developed for our first GASCAN, and are excited about the experiments we are developing for our second GASCAN, we have grown to appreciate the problems one can encounter. These problems have included the identification and acquisition of engineering design aids, documentation methods, experiment integration coordination and designing for safety. Each of these will be discussed briefly below.

Development Aids

We recognized early in the development of our experiments that the students would benefit from certain engineering design tools. As a result, all of the design teams regularly use two important design tools. When developing their circuits, the schematic drawing package **SCHEMA** (Omation, Inc) is used. The circuits diagrams are easy to read and follow, fewer mistakes are made in testing and wiring boards, and changes are readily incorporated into the documentation.

Printed circuit boards are designed using the **smARTwork** (Wyntek, Inc) design tool. This aid is particularly useful since there are a number of companies that will mask a double sided board directly from a file on a disk. Again, corrections and updates are easily incorporated into the final board design.

Structural analysis is conducted using **ANSYS** implemented on a MicroVax II computer system. Students model the support structure using the wire-frame method and generate three-dimensional views to study the placement and interrelationship of the experimental modules. The model can then be used to identify the vibratory modes and to determine the lowest natural frequency as well as stress levels for prescribed acceleration inputs.

Finally, **ACLS-PC** has recently been acquired and will be used for drive system modeling and payload thermal analysis modeling.

Documentation

In addition to the aids noted above all reports are expected to be written using a word processor (**PC-WRITE**, Quicksoft) and where possible, graphs, charts and figures drawn using appropriate software design aids (**GEMDRAW**, Digital Research). The primary reasons for doing so are that it simplifies the transfer of knowledge from one project group to another over several years of experiment development, and the documentation job for the safety packages (PSDP, FSDP, P3SDP) is greatly simplified.

Coordination

When the individual experiments are "finished" there still remains the work of integrating the experiments onto

the structure, cabling them together and testing the final package. To accomplish these tasks for our first payload, we employed an electrical engineering graduate student for the spring and summer of 1986. This student verified that each individual experiment worked, integrated the experiments onto the support structure, cabled the experiments together and tested the final package. Along the way he also designed a power distribution and control box, rewrote the flight software for several of the experiments to account for updated flight and operational scenarios and helped prepare the required NASA safety documentation. From our perspective, probably no single person was more responsible for the final preparation and certification of the flight hardware than this graduate student.

VII. SUMMARY

The first set of experiments, otherwise known as G-408, developed as part of the MITRE/WPI Space Shuttle Program is ready to fly. A second set of experiments is currently being developed as part of a continuing multi-year program to design and build space flight experiments. Because of the care that we have taken in the development and testing of the experiments, we expect that they will function properly and return scientifically useful data upon post-flight data analysis.

ACKNOWLEDGEMENTS

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Electrochemical Growth of Linear Conducting Crystals in Microgravity

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EXPERIMENTER'S SYMPOSIUM
NASA GODDARD SPACE FLIGHT CENTER
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ABSTRACT

In recent years much attention has been given to the synthesis of linear conducting materials. These inorganic, organic, and polymeric materials have some very interesting electrical and optical properties, including low temperature superconductivity. The quest for methods to synthesize high-quality single crystals of these highly conducting materials has been a very important part of previous research. Because of the anisotropic nature of these compounds, impurities and defects will strongly influence the unique physical properties of such crystals. Investigations have demonstrated that electrochemical growth has provided the most reproducible and purest crystals thus far. Space, specifically microgravity, eliminates phenomena such as buoyancy driven convection, and could permit formation of crystals many times purer than the ones grown to date.

Several different linear conductors were flown on Get Away Special G-007 on board the Space Shuttle *Columbia*, STS 61-C, the first of a series of *Project Explorer* payloads. These compounds were grown by electrochemical methods, and the growth was monitored by photographs taken throughout the mission. Due to some thermal problems, however, no crystals of appreciable size were grown. The experimental results will be incorporated into improvements for the next two missions of *Project Explorer*, G-105 and G-608. The intent of this paper is to discuss the results and conclusions of the first mission, along with the modifications being made for the next two missions.

Introduction

Project Explorer's first mission contained three student experiments, including a Linear Conducting Crystal Growth experiment, and one experiment prepared by the Marshall Amateur Radio Club (MARC). Although all experiments operated as planned, the thermal environment was much colder than originally anticipated. The MARC experiment worked exceptionally well with 486 voice messages recovered out of 1440 transmitted. Upon examining the returned experiments, it was determined that Radish Seed Germination experiment suffered from the cold environment and early shutdown. The Crystal Growth experiment also suffered from the cold environment, however, valuable information was obtained. Due to the partial success of the Crystal Growth experiment, it then was considered for a reflight on a future *Project Explorer* GAS canister. This experiment will fly on both G-105 and G-608 missions.

Experiment

This experiment is being conducted to study the effects of microgravity on the growth of linear chain conductors. These conductors have the interesting property of anisotropy: their conductivity is different when measured along different directions in the solid. Two of the materials belong to one of the most studied groups of linear conducting solids, salts of tetracyanoplatinate (TCP). These salts were first prepared in 1842 by W. Knop, who noted that the salt had the color and sheen of bronze. It was not until 1964 that Klaus Krogmann of the University of Stuttgart determined a structure. The TCP group has the shape of a flat disk, but in the TCP salts prepared by Knop the disks are stacked like poker chips in many parallel columns. In the 1970's the properties of organometallic conductors were examined and this new research subbranch of solid state physics flourished. Part of the impetus for the study of linear chain solids was provided in 1964 by W. A. Little of Standford University. He proposed that if a linear chain material could be designed to the correct specifications it might exhibit superconductivity not only at low temperatures, but also at room temperature.

The particular compounds which will be studied are: partially oxidized potassium tetracyanoplatinate (KCP), $K_{1.75}Pt(CN)_4 \cdot 1.5 H_2O$, and potassium tetracyanoplatinate bromide, $K_2Pt(CN)_4Br_{0.3} \cdot 3 H_2O$. These compounds both exhibit the columnar stacking typical of TCP complexes. Since the conductivity of a solid is determined by its electronic structure, this columnar stacking plays an important role in KCP electronic properties. In a highly conducting solid, orbitals of adjacent molecules and atoms overlap allowing electrons to readily move throughout the lattice. In the TCP complexes the platinum dz^2 orbitals extend above and below the TCP planes and allows for this overlap. In fact the Pt-Pt separation (2.88 A) is very close to the separation found in metallic platinum (2.79 A). Overlap of the dz^2 electron orbitals gives rise to a band of electron states delocalized along the platinum chain. This overlap permits conduction along the molecular chain, but H. R. Zeller reported that the conductivity between columns is 100,000 times lower than along the chain.

The result of a material exhibiting such an ordered linear structure is the extreme susceptibility to defects and disorder. In a conventional metallic three-dimensional conductor, point defects can *reduce* conductivity by scattering electrons. These same point defects can cause *complete loss* of conductivity along the effected chain in a linear chain material, because electrons can no longer detour around the block. Arthur Epstein notes that a typical crystal ($1.00 \times 1.00 \times 0.01$ mm^3) would contain approximately 1×10^8 parallel strands each of 3.5×10^6 collinear platinum atoms. Thus, purity levels (foreign impurities, end groups, and/or crystalline defects) of one part per million indicate that each stand averages more than three defects. These impurities could drastically alter the physical properties of the crystal, and most importantly, the electrical conductivity of the crystal.

In search of a synthesis that would lead to a defect free crystal, Arthur J. Epstein and Joel S. Miller devised the electrochemical techniques for preparing these crystals. When an electrical current is passed through a solution of potassium and tetracyanoplatinate ions,

partially oxidized KCP crystals form at the anode via electrochemical oxidation. KCP crystals grown in this way have room temperature conductivities 100,000 times greater than crystals prepared by more conventional means. If growing KCP crystals in the absence of gravity can produce crystals superior to the ones that have been grown to date, microgravity could become a valuable environment for pursuing this type of conductivity research and could ultimately lead to a better understanding of superconductivity.

Microgravity may offer several benefits to the electrochemical growth of these KCP complexes. In the early stage of their growth, KCP crystals form in a long, thin, needle-like structure, which thickens somewhat as the growth continues. In the initial growth period the crystals bend slightly due to their size and *weight*, placing a considerable amount of strain on the crystal lattice. In a low-gravity environment the lattice strain caused by this bending would be eliminated. Like any other solution crystal growth, the growing KCP crystal depletes the surrounding solution of solute as it grows. This depleted area has a lower density than the bulk solution and in a one gravity environment, it rises to the surface. It is this process that creates growth plumes which are characteristic of solution crystal growth. These growth plumes disturb the solution around the growing crystal and cause many microfluctuations at the crystal-solution interface. The elimination of such buoyancy driven convection may allow for the molecules to more properly allign, which would result in a more ordered crystal.

These different factors will be investigated to determine if they play an important role in the quality of the crystals grown. The crystals grown in low-gravity will be directly compared with crystals grown on the ground for various physical and electrical properties.

Results From G-007

G-007 was launched on STS 61-C January 12, 1986 and landed January 18, 1986 with a mission elapsed time of 6 Days, 2 hours 4 minutes. Photographs were taken at two hour intervals to monitor the progress of the crystal growth, and they revealed a crippling problem. At 10 hours and 10 minutes (10:10) the growth solution froze thus stopping all KCP growth. The temperature had continually decreased from 5.6 $^{\circ}$C at canister activation to -6.9 $^{\circ}$C during this initial growth period. Figure 1 shows the cell before it had frozen and figure 2 is a photograph of the frozen cell. The solution remained solid for the next 8 hours. A subsequent photograph, taken at 28:10, showed that the solution had liquefied. Finally at 43:10, the first crystals appear on the anode (figure 3), after which the canister temperature once again dropped and the solution remained frozen for the rest of the mission. Figure 4 shows a summary of the growth chamber and canister temperature values. The chamber temperature followed very closely to the canister temperature, indicating that the thermal control system used was inadequate. After G-007 was returned, several very small crystals were recovered (sizes < 1mm), however, these crystals were much too small for any physical measurements.
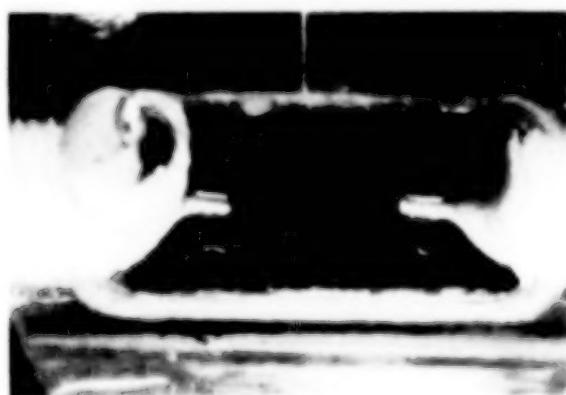
Figure 1
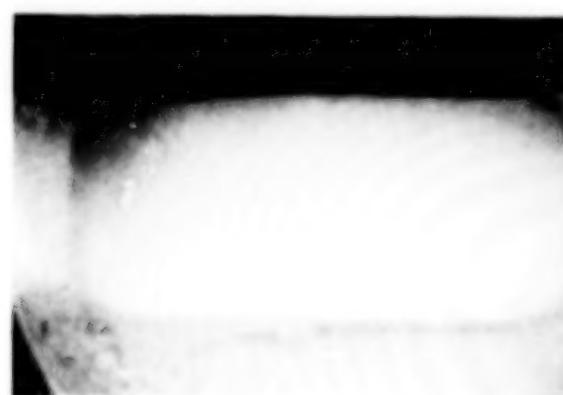
Figure 2

Figure 3

Figure 4

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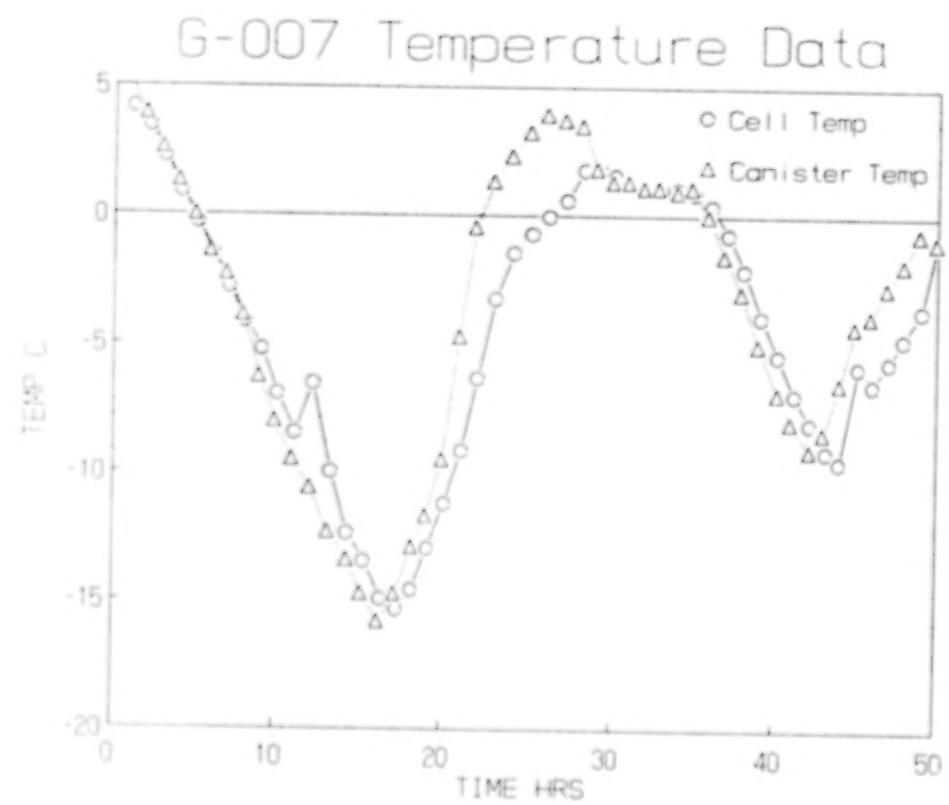
Modifications For G-105

G-105 was donated to the Consortium for Materials Development in Space at the University of Alabama in Huntsville (UAH), one of the nine Centers for Commercial Development of Space funded by NASA, for materials development experiments by faculty and students. Below is a summary of the experiments which will be included on G-105. Dr. Dwain Coble and Dr. Clyde Riley have agreed to allow one cell of linear conducting material to fly on their Electrodeposition experiment in G-105. The major components of the Electrodeposition experiment are shown in Figures 5 and 6. The experimental assembly will be mounted on an aluminum mounting plate which in turn is mounted to the GAS canister. The electrodeposition cells (Fig. 6) are stacked in two columns of four each. The cathode will be made of a thin sheet of platinum metal, while the anode will be modified to contain a small platinum stinger on which the crystals will grow.

Get Away Special G-105

Experiment 1	Separation of Aqueous Phases	Dr. Milton Harris
Experiment 2	Polymer Crystallization	Dr. Samuel McManus
Experiment 3	Monomer Crystallization	Dr. Milton Harris
Experiment 4	Electrodeposition and Co-Deposition	Dr. Dwain Coble Dr. Clyde Riley
Experiment 5	Cosmic Ray Determination	Dr. John C. Gregory

Figure 5

Figure 6

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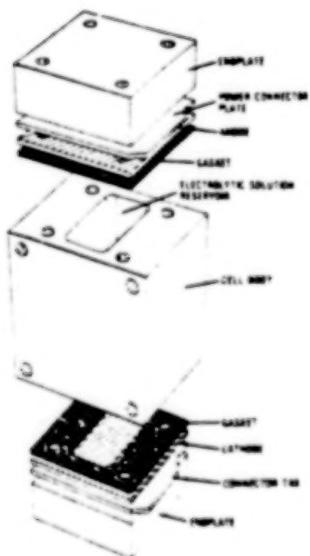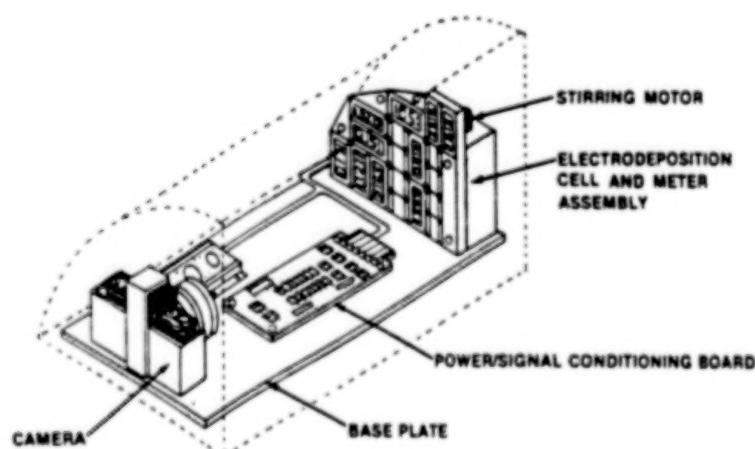
Modifications For G-608

The third *Explorer* payload is G-608 and contains only experiments proposed by students while attending *US Space Camp*. Below is a summary of the experiments which will be included on G-608.

Get Away Special G-608

Experiment 1	Insect Egg Growth	Bryan D. Agran
Experiment 2	Radish Seed Germination	Jay S. Andrews
Experiment 3	Yeast Growth	Greg T. Delory
Experiment 4	Bacterial Morphology	Tom P. Malone II
Experiment 5	Organometallic Crystal Growth	Raymond J. Cronise IV
Experiment 6	Silicon Crystal Growth	Seth Alain Watkins

The primary modifications for the crystal growth experiment will be in the thermal control system. Careful attention has been given to thermally isolate the growth chamber from the rest of the GAS package. The cells are attached to a glass cloth reinforced phenolic block which in turn is attached to the walls of the growth chamber. The growth chamber is then mounted to the experiment plate via two L-shaped support brackets that are also made of a glass reinforced phenolic material.

The Growth Chamber with three cells is shown in figure 7. Each cell will be fitted with a small thin film heater that will receive power from the canister SRB battery. The heaters will also be connected through a magnetic relay to a back-up dry cell power supply. This thermostatically controlled system will be activated during the shutdown procedures of G-608 to eliminate the possibility of freezing before the shuttle re-entry. The thermostat will be set at a minimum temperature to conserve the dry cell's power. This back-up thermal system in conjunction with the increased thermal isolation should provide the necessary improvements to the original G-007 flight hardware.

Growth Chamber
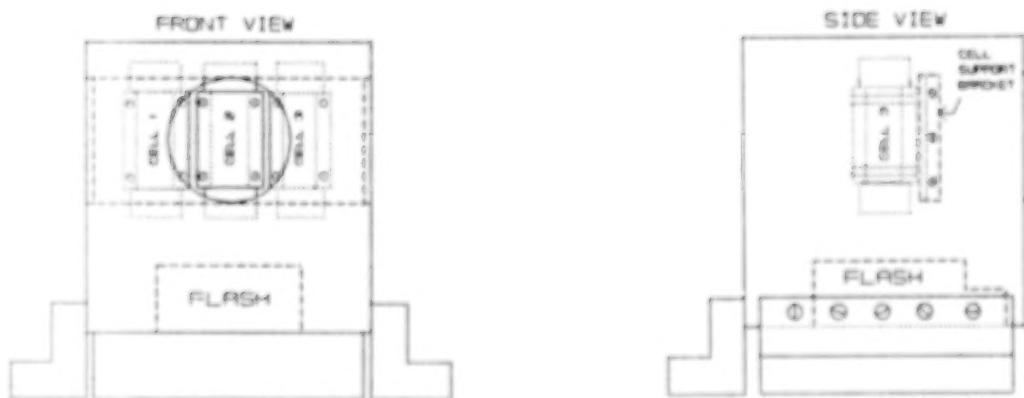
Figure 7

Conclusion

The first flight of this experiment on G-007 has given us a tremendous amount of valuable information to use for future *Explorer* flights. The most valuable information collected has been the thermal environment and SRB battery performance which were both monitored by the MARCE package. The SRB battery worked exceptionally well with more than 26 % reserve (See *MARCE Data Evaluation* by Edward F. Stluka in these proceedings). On the future flights, the SRB battery will be used as the primary power source and a dry cell battery pack will be used only for a backup. The importance of using all available methods of preventing thermal problems, has been a lesson learned by the *Project Explorer* team and other GAS experimenters. It is not always the best answer to just "use a bigger heater." Hopefully the increased thermal isolation in conjunction with better insulation, will eliminate future thermal difficulties.

Acknowledgment

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PLANET X PROBE

A Fresh New Look At An Old Familiar Place

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Tom O'Brien   Chief Engineer   Medical University of South Carolina
Sharon Brower   Project Coordinator   Charleston County Public School District
Shelley Canright   NASA Education Coordinator   NASA Langley Research Center

ABSTRACT

PLANET X PROBE will utilize a G.A.S. payload to provide a large student population with a remote Earth sensing experimental package. To provide a cooperative as well as a competitive environment, the effort will be targeted at all grade levels and at schools in different geographical regions. "Landsat" capability will allow students to investigate the Earth, its physical makeup, its resources, and the impact of man. This project will also serve as an educational device to get students to stand back and take a fresh look at their home planet. The key element will be to treat the familiar Earth as an unknown planet with knowledge based only on what is observable and provable from the images obtained. This will allow for critical and analytical thinking, imagination, and add the excitement of new discovery to that which is well known. It will also provide a format for competitive defense of ideas.

Through participation in the project, students will take an active part in the whole range of experience including:

1. Mission planning, selection of specific goals and priorities, selection of equipment and formation of task groups and teams
2. Research and pilot projects to train the teams, development of a system to handle and analyze the data
3. Identification and recruitment of scientific mentors and dialogue with those mentors before, during, and after the mission
4. Selection of a student advisory team to be available during the mission for necessary decisions caused by changes in conditions
5. Analysis of data and compilation of findings to answer selected questions and to exploit unplanned incidental findings
6. Preparation of final reports, constructed along sound scientific principles with findings supported by specific evidence; logical speculation based on available evidence supported by a close adherence to the principles of critical thinking
7. Presentation and defense of findings before a meeting of competitive student groups and distinguished scientists in the field

EDUCATIONAL GOALS

The educational potential for this project falls into two major areas: the specific science lesson which can be derived from the payload itself and the scientific methodology, teamwork, and the forensic and critical thinking skills that can be taught by the preparation and defense of the findings.

Because the remote sensing of the Earth cuts across many disciplines and scientific skills, any grade level or science course can play a role.

Some examples:

ASTRONOMY - planetary science, a "Voyager"-type analysis of a planetary body based on remote imaging techniques

BIOLOGY/LIFESCIENCE - logical predictive modeling of likely animal forms, pollution effects on plant coverage, infrared studies of plant health

CHEMISTRY - Atmospheric analysis, prediction of likely compounds of minerals and fluids based on temperature and basic spectographic data provided by the astronomers

ECOLOGY/ENVIRONMENTAL SCIENCE - pollution impact studies, climatic and geographical effects on plant coverage, land use studies

EARTH SCIENCE - includes all of the disciplines on this list modified and targeted for the appropriate grade level, emphasis on the broader overview as opposed to the highly specific

GEOLOGY - study of landforms, analysis of the geological history of the planet as evidenced by observed landforms. Special studies, if available, of recent volcanoes and earthquake zones.

CARTOGRAPHY - orbital tract plotting, construction of overlay maps from sequential photographs

METEOROLOGY - weather pattern studies over the duration of the flight, cloud coverage studies, tracking of particular storms or other weather phenomena

TAXONOMY - selection of names for land masses, oceans, specific geological structures, and the planet itself

OCEANOGRAPHY/MARINE STUDIES - studies of major currents, studies of the coastal environment, and silt pollution problems

PHYSICAL GEOGRAPHY - the mapping and study of land areas and types of major structural features such as rivers and mountains

PHYSICS/PHYSICAL SCIENCE - orbital track analysis, electromagnetic spectral wavelength propagation and atmospheric absorption studies

Activities associated with each topic will be modified to meet the educational level of the students.
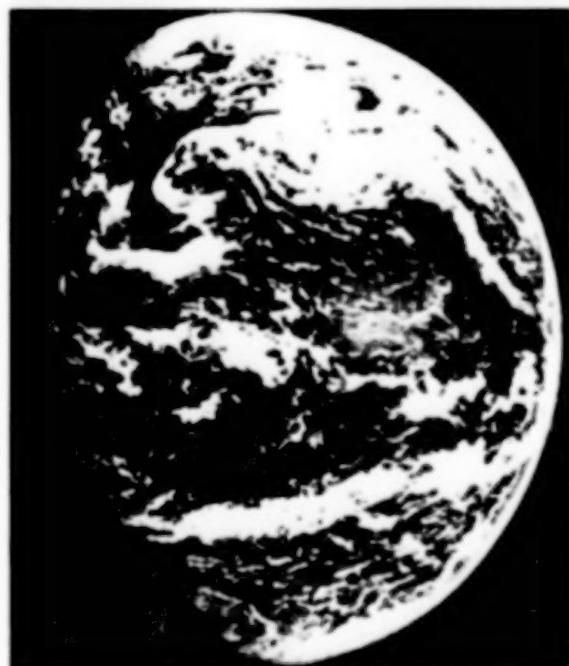
"On the way to the moon, man discovered the Earth."-- Norman Cousins

In addition to the scientific data derived from remote images, the structure of the project will be designed to teach indirect lessons in methodology and thought patterns. The fact that the students will have to take an unprejudiced, fresh view with limited data of an already well known planet will force them to analyze data critically and to base findings only on that which is demonstrated by the actual evidence. This is one of the most vital and most difficult techniques of scientific inquiry. The necessity of defending all conclusions before an audience of competitive student investigators will quickly detect any failure to document conclusions or to adequately consider alternatives.

The planning of the mission will teach the necessity of setting priorities and making trade-offs to maximize data. The limited number of cameras, lenses and film types available on a single flight will require the students to carefully select a package where equipment choices for one inquiry will not eliminate data collection in a different area. This type of decision is common in scientific inquiry where, for example, the Voyager team had to decide how much time to devote to a particular moon, while sacrificing available time to study the planetary rings. The preparation of reports for presentation will involve language and communication skills as well as scientific skills. In a competitive environment, the team able to make the best presentation will have the best expectation of having its findings adopted in the final report.

PLANET X PROBE can utilize the Charleston County Public School District CAN DO payload in its present form without major modification. The major addition would be a passive sensor to detect when the payload is pointed towards the daylight side of the Earth. The payload has the capability to mount four 250 exposure Nikon cameras. Lenses can be selected from any focal length from extreme wide angle up to a 500 mm telephoto lens. This would seem to cover any likely requirements for angular coverage.

Film selection can be made from a wide variety of black & white film and filter combinations to cover any particular wavelength from infrared through visible light and including the near ultraviolet. Color films can also be used for true color, true color minus ultraviolet, or false color infrared. This essentially covers all the capability of Landsat instrumentation except for thermal infrared and microwave which both require elaborate scanners.

Image quality should be excellent and fully comparable to that provided by Landsats and previous space flights. Depending on the orbital track, available Earth viewing time, and weather conditions, significant numbers of high quality images containing a large amount of useful data should be returned. Because the payload has been fully tested for vibration, shock, and thermal conditions and the cameras have proven totally reliable in the harsh environment of the Kuiper Airborne Observatory, there is every reason to expect a successful mission.
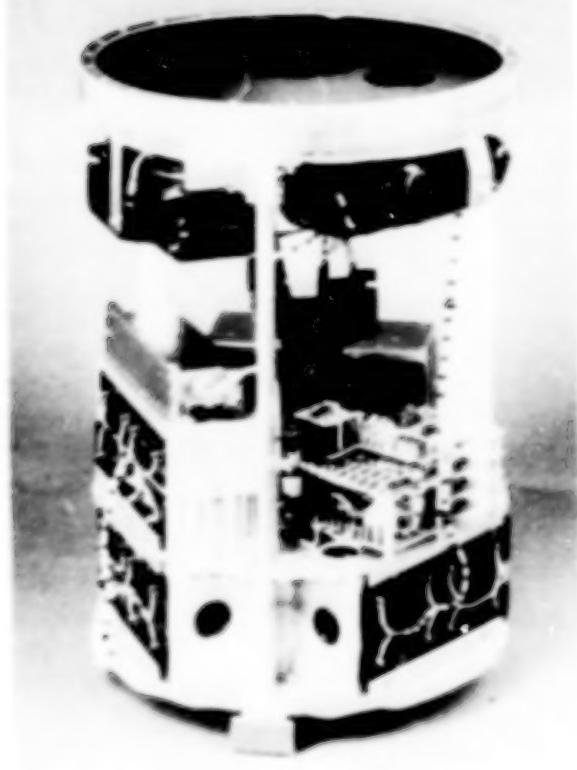
The CAN DO Payload

THE PAYLOAD

CAN DO is designed for a 5 cubic foot G.A.S. canister outfitted with a motorized door assembly, a 0.92 inch fused silica window, and sealed for flight with one atmosphere of dry nitrogen. The payload utilizes a 3-strut 6061-T6 aluminum design with the control electronics located on an intermediate plate which forms the top of the battery compartment. Power for all operation comes from redundant Duracell alkaline battery stacks that are electrically and thermally insulated in the lower compartment.

Four Nikon F3 35mm cameras with 250 exposure film backs and motor drives are mounted on the top plate with enough clearance to accept a

variety of lenses, from the wide angle 16mm to a 500mm reflex telephoto. The 35mm format has an impressive line of films from which to choose, covering the spectrum from false-color infrared to ultraviolet. In addition, multiple switched optical filters greatly enhance the detection capability of a camera and film. Each camera is controlled by an independent intervalometer which is programmed to take a series of photographs while switching optical filters and returning to a clear calibration shot at the end of the series. A separate day/night sensor can inhibit operation as desired, while a manual control loop from the GCD control can be selected up to the time of integration. In addition, an auto-failsafe override capable of taking a simple exposure series will take control in the event of an intervalometer failure. To advance film reliably at low mission temperatures, and to avoid any stress which could tear the film stock, an exponentially-ramped motor control voltage starts all film movement slowly.

The payload is insulated with a nitrogen gas circulation containment jacket of Rubatex EVA which is covered with a low emissivity surface of aluminized kapton to reduce thermal radiation. The dead air space between the mylar surface and the canister wall forms an additional thermal barrier. All thermally-conductive pathways are isolated with G-10 glass epoxy barriers, and thermal radiation from the payload face exposed through the window is reduced by a series of EVA layers and baffles. A stable thermal environment is maintained by separately switched and interlocked thermostatically-controlled heaters and low-volume fans. As a result, an operational mission temperature of -20°C can be held for up to ten days.

In addition to the primary photographic goal of CAN DO, the payload will house up to one hundred passive

58

MISSION PLAN

1. PRE-FLIGHT

student-designed and built research experiments. These experiments are housed in medical cryogenic storage vials which take up very little space and add less than five pounds to the total payload weight. The participating students will file with the Charleston County School District CAN DO team an abbreviated version of the P.A.R., Safety Matrix, Preliminary Safety Data Package, and a Final Safety Data Package, which will not only give them a sense of involvement from the beginning, but will be essential to payload paperwork.

Death Valley, California

The first step will be to identify regions for the development of research teams. One suggestion might be to form teams in partnership with NASA centers. Each participating school district will be responsible for recruiting students and structuring them into a unified team. Each team will identify local scientific advisors and set up a mentor system to fully involve these advisors at the onset of the project. Adequate means (newsletter, computer bulletin board, etc.) will be set up to facilitate communications between the school districts.

Each team will independently decide on specific areas of inquiry and questions to be addressed. They will select representatives to attend the pre-flight planning meeting. Team representatives will present their agendas at the pre-flight planning meeting and, along with the scientific advisors and the CAN DO Engineers, will select appropriate instrumentation and design the mission plan. Films, lenses, and cameras will be selected at this time, and the CAN DO Engineering Team will be responsible for preparing the payload based on the requirements of the student investigators.

The teams will then prepare themselves by research, interaction with mentors, and pilot studies to interpret the data when available. Airborne studies of the local region can be used to practice interpretation of remote images.

OPERATIONAL

This type of payload precludes much active involvement during the Shuttle flight. However, an advisory group of team leaders would be available to make decisions if required. For example, a change in

mission duration might require certain decisions to be made regarding payload activation and firing rate or schedule. Most activities during the flight will be aimed at allowing the students to enjoy the excitement and national attention the flight will create. Students will be encouraged to witness the launch, and arrangements will be made to allow selected representatives to monitor the flight from the control room. Other students can follow flight activities by radio (as relayed by the Goddard Amateur Radio Club and others) and by television (NASA Select). Each team will want to take advantage of the publicity and public relation possibilities of the flight through support materials and press kits generated by the CAN DO team and by NASA Public Affairs.

POST-FLIGHT

After retrieval of the payload and the processing and printing of the resulting images, the material will be distributed to the teams. According to their individual plan, each team will circulate the material, analyze the pictures, and draw their conclusions. The results from each study will be coordinated so that each regional team can draw up a single unified report summarizing their findings. They will then select their representatives to carry these findings to the national symposium.

During the symposium, the findings will be presented in individual research topic meetings where each team will be required to defend their own conclusions. Each topic group will then prepare a joint report which will be delivered to the entire group as a scientific presentation. These presentations will be criticized by the scientists from the various fields. A final report will be written and distributed to all participating schools along with the comments of experts in the field.
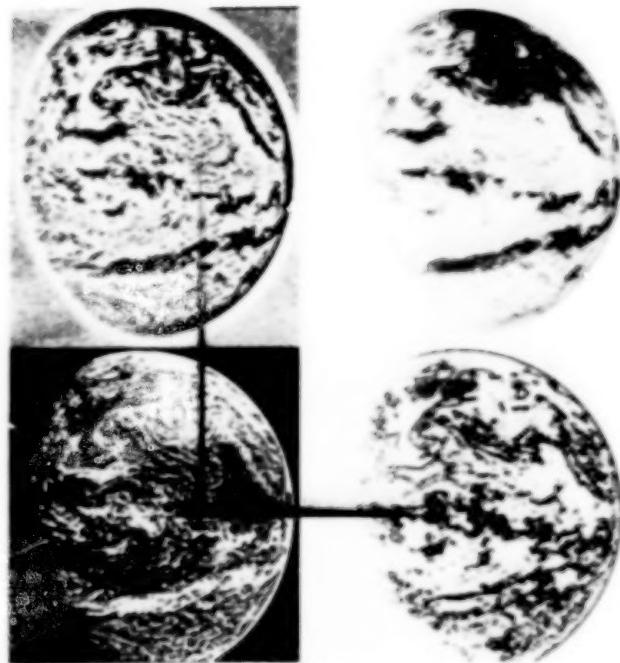
Digital image processing will provide more information and more education.

CURRENT STATUS

At the present time, we have a workable payload, a G.A.S. reservation number, and an experienced CAN DO team. PLANET X PROBE as presented in this paper is deliberately left as open as possible. One of the main goals is the establishment of multiple teams in various parts of the country to allow for maximum input and exchange of ideas. As the teams develop, more and more educators will become involved, and it is they who are the best source of ideas on how to achieve the most educational impact. As students are brought into the program, they will be presented with the widest possible range of options in mission design. The result will be a program that will evolve and develop through the interaction of

student investigators, expert mentors, professional educators, and the CAN DO support team. The final PLANET X PROBE program will be the result of the ideas and hard work of everyone involved.

The level of funding support will be based on the size and number of school districts involved. Since the payload itself is already designed, built, and tested, the hardware costs will be minimal. The cost for meetings, publication, and educational activities will be shared by the school districts involved. Additional support will be solicited from public and private institutions who are committed to the improvement of science education in our schools.

FUTURE GROWTH

PLANET X PROBE has the great advantage of being designed to study a dynamic and constantly changing object. Any one shuttle flight will only image a small percentage of the Earth's surface, and much of that will be partially or totally obscured by weather and atmospheric conditions. Additional flight images can be treated as a separate project or added to the existing data base. The program can be repeated with new student teams, and their conclusions will be totally different.

This type of Earth observation could be a highly attractive candidate for the future Space Station. It will require relatively little power and space, but will continue to operate over a long time span. Images will be returned as film, electronically, or a combination of both.

PILOT WORKSHOPS

Preliminary student input on PLANET X PROBE has been obtained through a limited number of workshops at meetings such as the South Carolina Junior Academy of Science. This has proven to be an effective

method of testing ideas, assessing areas of special interest, and tapping the invaluable resource of youthful imagination. Already, certain fields have emerged as ones with a high interest level. Many students want to study coastal environmental problems such as erosion, pollution, and the impact of development. This interest is as strong among students living inland as among those living near the ocean. Other forms of pollution also score strongly as areas of interest.

Another important conclusion from the pilot workshops was that the students were fully capable of selecting a suitable compliment of lenses and films with only a brief training period. After one hour of instruction in which the students were shown examples of the coverage of the different focal length lenses and the spectral response of the different films, they designed packages in order to study questions in which they were interested. Each package included four lens/film combinations. Through interaction and compromise, one package was developed that would meet the research needs of all. Within two hours, the student teams were able to arrive at a research design that was well balanced and appropriate to meet the stated goals.
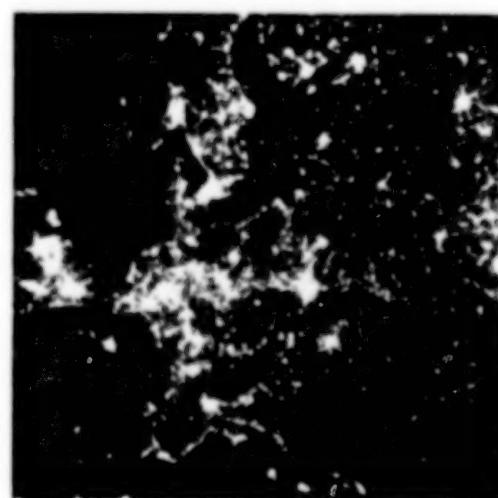
Western Europe at night.

61

ACTIVE RESEARCH

Although PLANET X PROBE was originally invisioned as a passive observational experiment, workshop students have suggested an exciting active research addition. Fascinated by photos showing the patterns of city lights taken on Earth's night side, the students began to imagine ways in which they could actively change measurable parameters. Basically, the main question was whether students, as a group, could create a significant enough change in their local area to be observed from Earth orbit. For example, if every student in an urban area turned off as many lights as he could, would the city look different? Obviously, each individual light would make only an infinitesimal contribution as to what would be seen from space, but there would be many students. If each student would get several neighbors to cooperate, the effect could be quite dramatic. All students in, say, Washington could turn on lights, while students in Baltimore turned them off...or checkerboard a whole state, county by county...or turn them off at an exact time....

Such an experiment would require a degree of active control and coordination not usually available to a G.A.S. payload. The lesson to be learned would be that students could have an impact, if they worked together. Collectively, they could alter the Earth in such a dramatic way that it could be made visible from space. If the students could create that much change by cooperatively doing something as simple as turning off a light, then it would also be in their power to exert more lasting influence on their environment.

STUDENTS AND SPACE

There is a crisis in American education today. Current figures show that the educational system is failing to interest enough students in science as a career. There will not be replacements for the scientists who will soon retire, let alone provide for the growth that will be needed in a highly competitive and technological future. Unfortunately, circumstances have been unkind to that best of all motivators—the space program. Innovative programs such as the LDEF Seed experiment and the Teacher in Space have been negated by fate at the very time when classroom involvement is so badly needed. Other worthwhile programs such as Young Astronauts and Space Camp do a tremendous job of reinforcing those students already interested in science, but by their natures, are not available to all students. To reach more students, it is necessary to design programs that can be fully integrated into the normal classroom curricula. PLANET X PROBE has the potential to provide teachers with a powerful tool to support the scientific lessons that are being taught every day, and to make them more effective and exciting. To this goal, the CAN DO team dedicates its efforts.
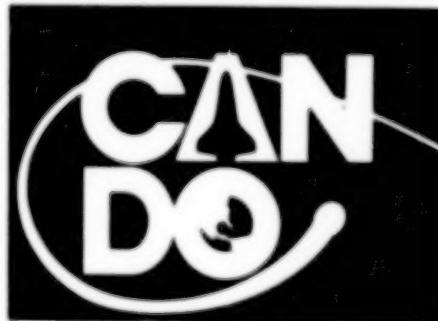
Protein-Crystal Growth Experiment (Planned)

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ABSTRACT

To evaluate the effectiveness of a microgravity environment on protein-crystal growth, we developed a system using $5-ft^3$ Get Away Special (GAS) payload canister. In our experiment, protein (myoglobin) will be simultaneously crystallized from an aqueous solution in 16 crystallization units using three types of crystallization methods, i.e., batch, vapor diffusion, and free-interface diffusion. Each unit has two compartments: one for the protein solution and the other for the ammonium sulfate solution. Compartments are separated by thick acrylic or thin stainless steel plates. Crystallization will be started by sliding out the plates, then will be periodically recorded up to 120 hours by a still camera. The temperature will be passively controlled by a phase-transition thermal storage component and recorded in IC memory throughout the experiment. We can thereby evaluate microgravity environments for protein-crystal growth by comparing crystallization in space with that on earth.

INTRODUCTION

Recent advances in space transportation systems have opened the way to using environments in space, such as microgravity, ultra-high vacuum and cosmic radiation. Biotechnological use shows promise of being one of the most fruitful of the many application proposed thus far.

Determining the three-dimensional structure of protein is a basic and vital step in developing new technology, protein engineering, to improve some protein functions. X-ray diffraction analysis of protein crystals is

63

currently the most reliable way of determining protein structures, because it enables us to determine the absolute atomic coordinates of protein. The technique has significant problems, however, such as the nonreproducibility of nucleation and the difficulty in making well-ordered protein crystal enough for high resolution X-ray diffraction analysis.

Although, as yet, there is no effective way of controlling protein-nucleation, Littke and John[1] recently reported that a microgravity environment accelerates crystal nucleation. Disorders caused by convection can conceivably be eliminated in a microgravity environment that is free of convection and sedimentation[2]. It is here that working in space becomes of interest.

The G-459 payload, protein crystallization experiment system, was sponsored by The Mechanical Social Systems Foundation, and development was done by Fujitsu Limited in cooperation with Fujitsu Laboratories Ltd. The experiment in space will be done by Society of Japanese Aerospace Companies in cooperation with Fujitsu Limited.

OBJECTIVES

The objectives of the project are to evaluate the usefulness of a microgravity environment in growing protein crystal and to determine which of the methods explored is most effective.

To achieve these objectives, we will attempt to crystallize protein, simultaneously, using three methods, and photograph nucleation and crystal growth processes. We selected myoglobin because it crystallizes easely, has a brownish color that makes it easy to observe and is stable for months in an aqueous solution.

PROCEDURES

Protein, as a polyionic electrolyte with a high molecular weight and a unique three-dimensional structure, can be crystallized from a modelately hypersaturated aqueous solution by salting out. Hypersaturation is achieved several ways including batch, equilibrium dialysis, temperature gradient, vapor diffusion, and free-interface diffusion. We have chosen three of these for the experiment: 1. batch, in which protein and ammonium sulfate solutions are thoroughly mixed, 2. vapor diffusion, in which solutions are separated by a gaseous diffusion layer, and 3. free-interface diffusion, in which solutions contact in what is called free interface.

STRUCTURE AND FUNCTION

Figure 1 gives the structure and Figure 2 the block diagram of the system, which includes lead-acid batteries, a sequence controller, IC memory, a still camera, and the experiment module. The system can perform experiments simultaneously for up to 120 hours. We have chosen a new option, called Baroswitch, for the GAS system, to extend the life of the experiment to the maximum. Figure 3 shows the experiment module, in which 16 crystallization units with sliding plates are set radially around a mirror rotated by one stepping motor for sequential observation of each unit. Sliding plates are linked to a triangular plate, just over the units, that can be driven by another stepping motor and three synchronously rotating ball screws to slide

the plates out.

The three groups of crystallization units are the same size but have structures differing with the crystallization method, as shown in Table 1. The batch and free-interface diffusion units are nearly the same, except for the batch unit's small magnet used to mix the solution in the initial stage. The unit for vapor diffusion has thick acrylic plates, instead of thin stainless steel plates to form an air gap between two compartments.

Crystals will be photographed periodically up to 120 hours with a still camera having a motor-driven film winder and a 30-foot film attachment. A ring-flash light just beneath crystallization units flashes synchronously with the flipping of the camera shutter. A lens is attached to a cover plate of the experiment module.

THERMAL CONTROL

Crystal solubility and growth rate generally depend on temperature, it desirable to control temperature as precisely as possible. Restrictions on electricity led us to choose passive thermal control consisting of foam thermal insulator and a thermal storage component that use the exo- and endo-thermic phase transition reaction of inorganic hydrates. This protects crystals from the thermal fluctuation of the external environment and the heat generation accompanying battery discharge. Table 2 gives an example of hydrate composition. The transition temperature is adjusted by changing hydrate composition.

PRELIMINARY EXPERIMENT

A stand-by period for the GAS system that lasts more than a few months may be a factor critical to the experiment's success, because long-term storage of the protein solution at room temperature is abnormal and may denature the protein. This make it vital that we thoroughly examine the stability of the protein solution.

Figure 4 shows crystals grown in the crystallization unit by free-interface diffusion from a freshly prepared myoglobin solution.

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2) L. J. DeLucas, F. L. Suddath, R. Snyder, R. Naumann, M. B. Broom, M. Pusey, V. Yost, B. Herren, D. Carter, B. Nelson, E. J. Meehan, A. McPherson, and C. B. Bugg, J. Cryst. Growth, 76, 681-693 (1986)

Table 1 Crystallization methods

Method	Principle	On Earth	In Space
Free-interface diffusion			
Batch			
Vapor diffusion			

☐ Protein solution   ▨ Mixture

▨ Precipitate solution
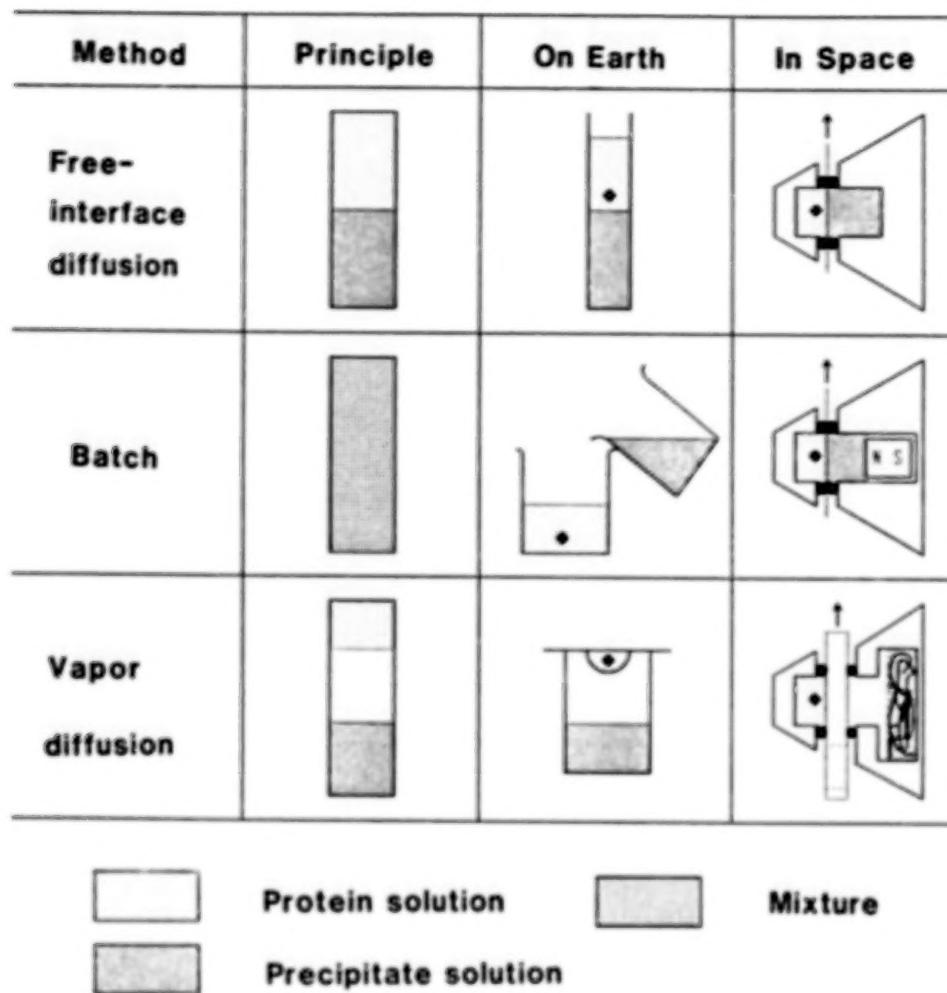
Table 2 Thermal storage component composition

Hydrate	Content (wt%)	Transition Temperature (°C)
$CaCl_2 \cdot 6H_2O$	88	
$MgCl_2 \cdot 6H_2O$	9	25 ± 0.5
$Ba(OH)_2 \cdot 8H_2O$[*1]	3	

*1: As nucleator
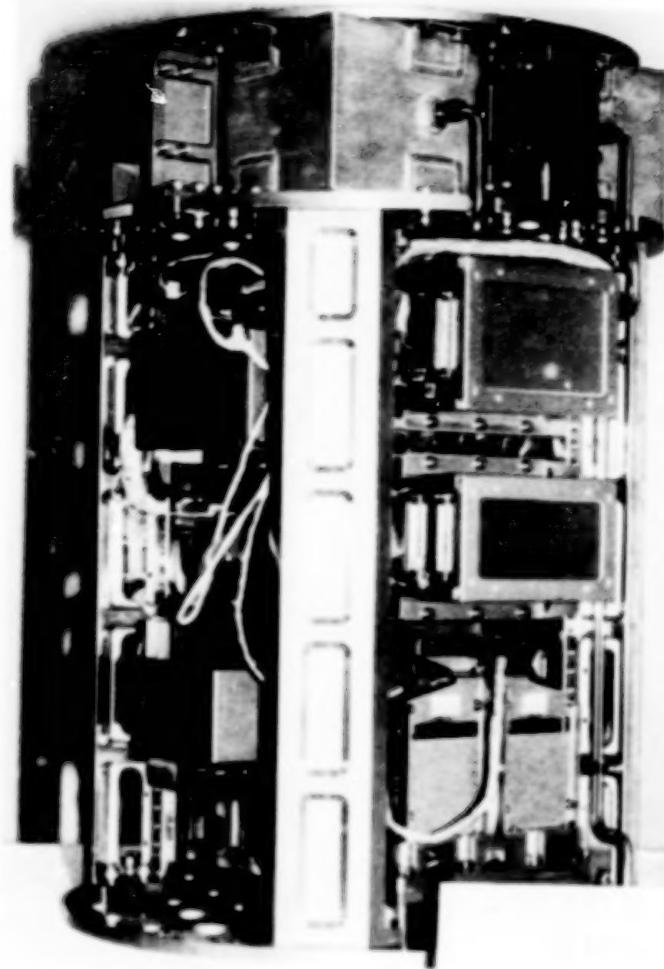
Figure 1

G-459 payload
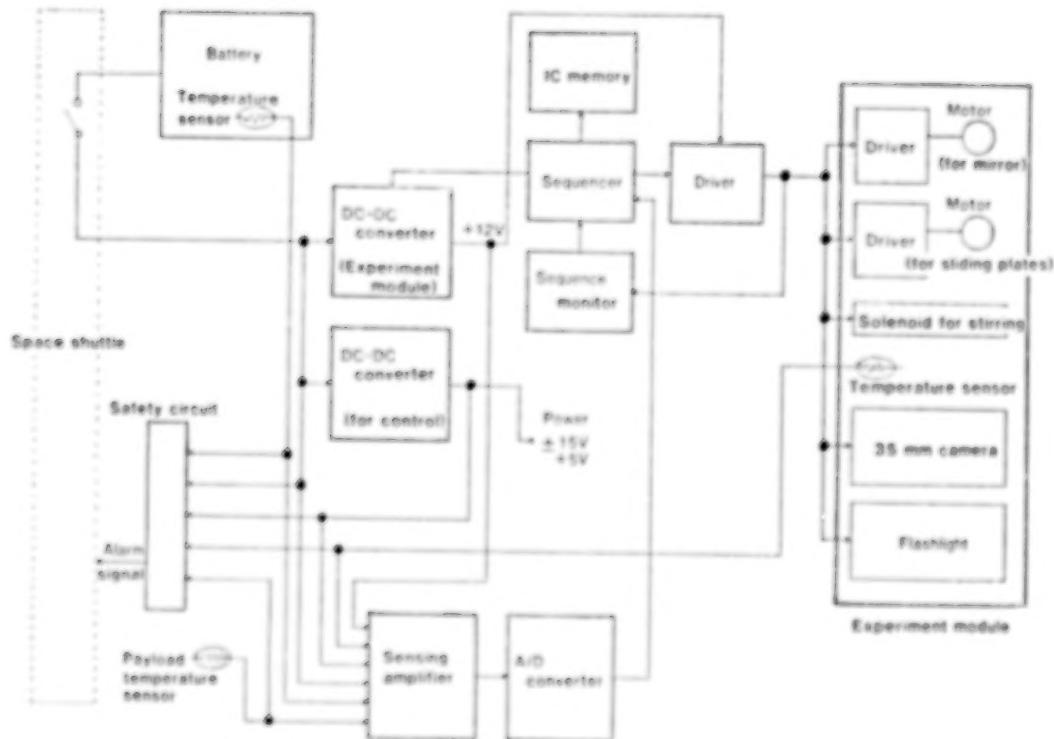
Figure 2 Block diagram
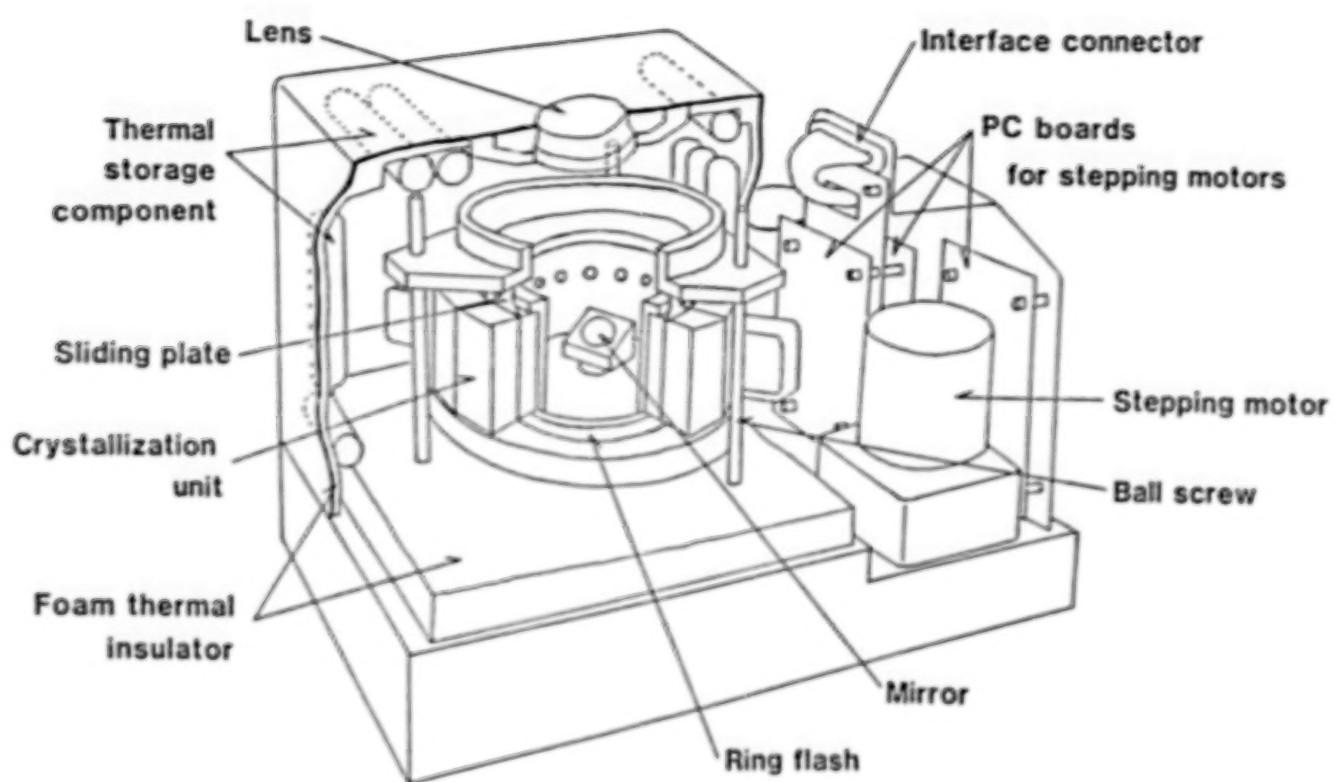
Figure 3 Experiment module
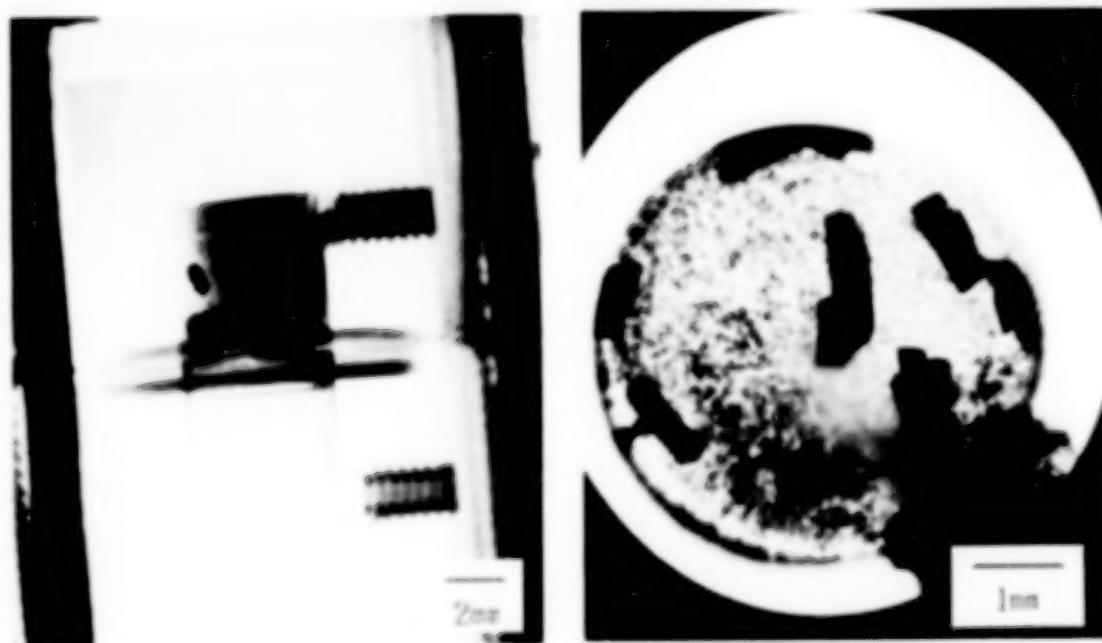
Figure 4 Crystals grown in the crystallization unit

68

THE PHOTONS PAYLOAD, G-494; A LEARNING EXPERIENCE

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ABSTRACT

PHOTONS (Photometric Thermospheric Oxygen Nightglow Study) is an optical remote sensing payload developed for GAS flight by the National Research Council of Canada. The device is extremely sensitive and is suitable for making measurements of low intensity, aeronomically generated atmospheric emissions in the nadir and the limb and of Shuttle ram glow. The unit uses a sealed canister and UV transmitting viewing ports. This is the first GAS payload to use a sealed viewing window. That window was developed by Bristol Aerospace Limited of Winnipeg, Canada. An engineering flight occurred on STS 61-C. During that flight PHOTONS received one hour of operation and aeronomic observations were made. Good diagnostic data were obtained and the science part of the experiment malfunctioned. Post flight inspection revealed that the payload was in perfect working order except for total failure of the photomultiplier detectors. The experiment and the payload are described and the flight results are discussed along with the cause of the malfunctions. It is shown that enough has been learned from the flight diagnostic data and about the cause of the malfunction to conclude that the engineering flight was successful and that subsequent flights of the PHOTONS payload will be productive.

INTRODUCTION

After the Canadian sub-orbital rocket program was terminated in 1984 it was necessary to find a replacement carrier for the affected aeronomy experiments. This carrier might also be expected to serve as a test-bed for other payloads that are developed as part of the Canadian space program. To this end an effort was made to explore the feasibility of using the STS Get Away Special (GAS) as the replacement carrier. The plan devised was to make a simple engineering flight with the requirement that the payload be capable of doing aeronomic science as well. This meant that the unit to be developed had to carry the necessary science instrumentation as well as the broad array of diagnostics required to assess its performance.

Two basic science areas were addressed: oxygen chemistry in the lower thermosphere and Space Shuttle ram glow. Both objectives required the use of extremely sensitive light measuring instruments (photometers) capable of detecting an emission rate less than one Rayleigh. The Rayleigh (R) is an absolute unit defining a column surface brightness for an extended source (Hunten et al., 1956). This sensitivity makes the experiment suitable for measuring the Shuttle ram glow parameters at levels previously unachieved. The science issues are discussed in detail by Harris et al. (1987). Because of the nature of the science problem the experiment is named Photometric Thermospheric Oxygen Nightglow Study or PHOTONS. Flight occurred on STS 61-C (Columbia) in January, 1986 and one hour of operation was achieved. The NASA identification code for this experiment is G-494.

SCIENCE INSTRUMENTS

It was intended that the flight hardware be as simple as possible consistent with a reasonable scientific return. This dictated that the payload would not use imaging detectors and there would be no direct recording of spectra. The observable list in Table 1 requires the measurement of emission rates at 7 wavelengths. It was therefore decided to make the observations with a 7 channel photometer. It was also decided to use 7 parallel detectors rather than a complex filter wheel device. The nominal bandwidths of the selected filters are wide so that there was no requirement for temperature control. The design values are given in Table 1. In addition a field of view of $8°$ was adopted to maintain adequate sensitivity for nadir work with the Herzberg I band system and also for ram glow observations at sub-Rayleigh emission rates. The photomultipliers used were Hamanatsu photon counting types R943-02 and R212-UH.

Table 1. The observables in PHOTONS and the design instrumental functions at a temperature of $-5°C$. The measured flight functions are given in Table 4.

Channel	Emitter	Wavelength (nm)	FWHM (nm)
1	$O_2(A^3\Sigma_u^+)$	287.8	8.0
2	$O(^1S)$	557.7	2.0
3	continuum	625.0	1.0
4	$O(^1D)$	630.0	2.0
5	$O_2(b^1\Sigma_g^+)(0,0)$	764.0	3.0
6	continuum	826.0	1.0
7	$O_2(b^1\Sigma_g^+)(0,1)$	865.3	8.0

The absolute calibration and detection limit for each photometer is included in Table 4. The thresholds are well below the signals expected in the nadir nightglow, consequently the signal-to-noise ratios are more than adequate for the science requirements. In flight calibration was achieved through the use of calibrated incandescent sources in front of the filters in the visible and IR channels and a

Table 2. The basic PHOTONS orbit sequence for STS 61-C (SDA is solar depression angle).

Sequence Elapsed Time (s)	Details	SDA°*
0	GCD experiment activation at local sunset	0
360	initiate warmup	24
420	initiate calibration	28
450	initiate dark count	30
480	initiate MDA open	33.5
503	initiate data acquisition	118.5
1777	initiate MDA close	120
1800	initiate calibration	120
1830	initiate dark count	122
1860	sequencer termination	124
2460 ≥600	GCD experiment deactivation	---

* $0°-90°$ depressed sun, sunset
  $90°-180°$ depressed sun, sunrise

light emitting diode behind the filter for the UV photometer. These sources were operated according to the sequence given in Table 2.

ENGINEERING REQUIREMENTS

Because the experiment was intended to do optical remote sensing a motorized door assembly (MDA) was required for mechanical protection. The door also allowed a controlled environment for the in flight calibrations and dark count determinations. The door weighs 15.9 kg and that figure had to be included in the overall payload weight envelope. This coupled with the weight of the viewing window assembly required careful planning in order to not exceed the 90.7 kg limit. The flight weight achieved was 84.8 kg.

One of the major design decisions in order to maintain a simple philosophy for the experiment was to have the instruments look through a window so that the GAS canister was maintained at nominal atmospheric pressure. This unit was developed under contract by Bristol Aerospace Limited. The window plate is shown in Fig. 1. It contains four viewing ports. Two have diameters of 16.5 cm and the remaining two have diameters of 7.6 cm. One of the smaller ports is for the bright light protection sensor which is described later. All the windows are UV transmitting. The window material is Dynasil UV1000 having a cutoff wavelength below 185 nm. The weight of the entire device is 7.7 kg.

Fig. 1. Inside view of the payload viewing window.

A major concern during the payload design was the uncertain effects arising from the temperatures that the unit might experience during storage and flight. Remote sensing through a GAS window from Shuttle was completely new. A temperature of -5°C was used as the baseline for design. The effect of temperature cycling of the filters was carefully monitored through a number of temperature sensors and by making preflight measurements of absolute sensitivity and transmission functions over the flight design temperature range of -30° through +30°C. A large array of

other housekeeping information was also taken. This included payload pressure and all the voltages and currents required to establish that the payload was in good operating condition. Pressure was an important diagnostic parameter because of the high voltages present within the canister. To protect the experiment against bright light sources such as the sun and the sunlit atmosphere, a redundant bright light detector, using a Motorola MRD450 NPN silicon phototransistor, was included in the payload.

Redundant data storage systems and a single data acquisition system utilizing a multiplexer strobed at 2 Hz were used. The data storage systems were EPROMS and a Sea Data model 633M/80 tape recorder. The EPROMS were the primary data set because of their superior error rate relative to the recorder. The system was designed for a maximum of five observation sequences; one of these is outlined in Table 2. This requirement determined the memory size at 320 kilobytes. Photometer sample counts were made with a 24 bit counter. Those data words were then formatted into 2 bytes including the 11 most significant bits, 4 bits to record the number of right shifts used in the data compression and one parity bit. The sample window was 50 milliseconds in all cases.

The timing of each Gas Control Decoder (GCD) event is recorded with a timing precision of ±1 min. In addition the timing precision adopted by NASA for scheduled GCD events, e.g., switch actions, was ±2 min. This constraint caused serious difficulty in calibrating the real time clock. It was planned to obtain experiment pointing from the spacecraft attitude file after the flight. In order to do this with adequate precision, time had to be known with a maximum error of ±2.8 s. The clock had to be set approximately 3 months prior to flight, therefore the expected clock drift before flight could not be accurately estimated. It is estimated that for a storage temperature of 23°C and a storage period of 106 days the clock would be ahead by about 5 min during flight. The uncertainty in this number is ±25 s which is clearly an inadequate timing precision. The other available alternative was to calibrate the clock as soon as possible after the flight. This involves a period of only 2 weeks and a resulting uncertainty of only ±3 s; this was the approach used.

MISSION REQUIREMENTS

The mission requirements for the engineering flight tests were very simple. Success would be signified by satisfactory operation of the payload, in the science mode, over one or more observation periods. This involves correct sequencing of the science instruments, data acquisition and recording of diagnostics. There were two science mission requirements. The first was to make measurements of the airglow components listed in Table 1 over at least one orbit. The second was to make ram glow measurements at the same wavelengths while looking in the local zenith. The latter permits the ram glow to be studied and provides any corrections required for the airglow results. All of these observations were to take place in shadow with the photometers looking out of the payload bay along the Orbiter -Z axis.

A series of observations of the Earth's limb was considered to be the most desirable data set, however, complex pointing manoeuvres such as scans are not available to GAS experiments on demand and can only be achieved as targets of opportunity. In addition simple pointing directions are normally provided with typical errors of ±15°. These pointing errors made it impractical to try for predictable positioning of the field on the limb but were quite acceptable for nadir and zenith work. Consequently the flight plan was built around nadir and deep space operations, all the while hoping that an opportunity would arise for one or more

72

limb scans to be recorded. In the event that altitude distributions of emissions could not be determined directly from the data the backup position was to determine the total column emission rate in the nadir and infer height profiles from previous sounding rocket measurements.

The orbit flight sequence for both science mission requirements is listed in Table 2. The sequence elapsed time is given in column 1. The full sequence begins with the astronaut activated GCD relay operation at the Orbiter sunset or a solar depression angle of zero degrees. Solar depression angle (SDA) is given in column 3. The solar depression angles are based on an assumed low inclination circular orbit at 300 km altitude and an orbit period of 90 minutes. Because shadow observations were required it was decided to key the entire sequence on local sunset as it was an easy event for the responsible Payload Specialist to identify. The 6 minute wait at the beginning serves only to delay observation until a SDA of about 30° is reached. The full sequence allows for pre- and post-observation calibrations and dark count determinations and 1274 seconds of data acquisition. The 600 second error accompanying the time for GCD deactivation is included because NASA could not guarantee a timing precision greater than this. The event was therefore delayed so that it would not impact on the observations.

FLIGHT PERFORMANCE

The experiment achieved two observing periods or approximately one hour of operating time from a 325 km, circular orbit inclined at 28.5° to the equator. The first period was devoted to the nadir viewing mode and the second included a limb scan as an experiment of opportunity instead of zenith observations. Following post flight recovery of the payload the data were inspected with rather unexpected results. Firstly there was no evidence of any data having been recorded during the first pass. In addition there was a complete data set corresponding to the second pass and all the diagnostics were valid but all the photometer counts were zero. This initiated a comprehensive study of the payload mainframe hardware, software and the science instruments. The problems were identified and are discussed below.

The first observation sequence was initiated but not executed because of an error in the sequencer program. The error, while simple, went undetected in the preflight tests. When a sequence is terminated prematurely a flag is set in the PHOTONS sequencer that prevents the next sequence from initiating. All the next sequence initiation accomplishes, following premature termination, is to reset the flag so that the next set of observations can take place normally. This reset permitted the second set of flight observations to be made. A premature termination of measurements during payload testing following preflight integration at Goddard Space Flight Center caused that flag to be set. That particular bug in the program escaped attention during the otherwise detailed preflight tests, i.e., it was never tested because it could not happen during flight and all real flight possibilities were tested.

The reason for the photometer failures was that all the photomultipliers had lost vacuum and it was initially believed that they had sustained mechanical damage during the powered portion of the flight. Further study revealed that they all had been poisoned only by helium. There was no spectrographic evidence of any other gas in the envelopes, which verified that the tubes had not leaked. Two tubes, one of each type, were further checked by Hamamatsu who confirmed the absence of mechanical damage. These tests verified that the tubes were suitable for surviving the environmental conditions encountered on Shuttle flights. The cause for the helium poisoning was the GAS canister overpressure, at 34.5 kPag using helium, which NASA

applied in order to verify that the canister seal was tight. It is known that synthetic fused silica, the tube envelope material, is very susceptible to penetration by helium. The canister was later purged with dry nitrogen and stored at a nominal pressure of one atmosphere until flight.

Further testing of the circuitry involved replacing the tubes with good ones. When this was done the photometers functioned normally. This result proved that the electronics had survived Shuttle Flight conditions. Thus, it is known that the photometers would have provided data had it not been for an identified programming error and an unfortunate choice by NASA for the type of leak test applied to the canister. Detailed testing of the payload mainframe showed that it performed flawlessly after the flight except for the software error noted above.

Table 3. Temperatures experienced in four GAS payloads on three missions. All data except those for G-494 (PHOTONS) are from Butler (1986). Columns 3 and 4 show temperatures at a MET of 54 hours and the mission minimum respectively. See text for details.

Payload	Mission	T °C 54 hr MET	T °C minimum
G-345	STS 7	-7	-19
G-347	STS 8	-8	-11
G-470	STS 61-C	-5	-11
G-494	STS 61-C	+1	---

The first recorded night side pass was initiated at a mission elapsed time (MET) of about 54 hrs and 13 minutes. Until then the payload had not dissipated power. The array of temperature sensors in the payload all indicated a temperature of 1°C at that time. Selected temperature data from four GAS payloads, including PHOTONS, are given in Table 3. Temperatures corresponding to the MET of PHOTONS operation are listed in column 3 and the overall mission minima are shown in column 4. These results all correspond to dissipation free canisters. It can be seen that at 54 hrs MET PHOTONS was between 6° and 9° warmer than the others. The results also suggest that the minimum temperature reached by PHOTONS was in the range of -11° to -19°C, or warmer, if its temperature profile was comparable with those for the other GAS payloads. Unfortunately, the minimum temperature was not recorded. The PHOTONS measured internal temperature, and probably the entire flight profile, were well within the design operating range of -30° to +30°C for the photometers. Typical temperature variations throughout the payload were +2°C with area extremes ranging between 0° and +9° during the one data set recorded. The typical change of +2° corresponds to the extreme expected for 70 W input to an assumed equivalent of 84.8 kg of aluminum for 30 minutes with no external heat losses.

The experiment flew pressurized with dry nitrogen at a nominal pressure of one atmosphere. The pressure level set by NASA prior to flight is not accurately known but two very useful measurements by the internal transducer do exist. During flight at a MET of 54.2 hrs and a temperature of 1°C the internal pressure was 87.7 kPa. A second measurement was made after payload recovery, but prior to opening the unit, i.e., before breaking the seal. That measurement was 94.6 kPa at 23°C. Application of the thermodynamic gas equation to the flight measurement in order to normalize the 23° increased the value to 94.6 kPa. This value agrees exactly with the post flight atmosphere in the canister. It is therefore reasonable to assume that there

was no significant leakage of gas from the payload after the second flight turn on and that the seal on the viewing window worked well.

Table 4. PHOTONS transmission function and calibration data prior to and after the flight.

Channel	PREFLIGHT				POSTFLIGHT	
	λ_0 (nm)*	FWHM (nm)	Sensitivity (R/count)	Threshold (R)	λ_0 (nm)*	FWHM (nm)
1	288.3	7.3 ± .2	.27	1.3	288.0	7.2 ± .2
2	558.2	2.33 ± .07	.048	.19	558.3	2.41 ± .07
3	625.5	1.15 ± .04	.044	.20	625.3	1.11 ± .04
4	630.5	2.19 ± .07	.071	.14	630.4	2.22 ± .07
5	764.6	2.79 ± .09	.13	.41	764.8	2.66 ± .09
6	826.3	.92 ± .03	.079	.73	826.4	.96 ± .03
7	865.2	8.2 ± .3	.20	.45	865.2	7.9 ± .3

*The uncertainty in each center wavelength (λ_0) is ±.2 nm

The transmission function data before and after the flight are given in Table 4. It is possible only to give the absolute calibrations and instrument thresholds prior to flight because of the tube contamination by helium. Comparisons with new tubes would be meaningless because sensitivity changes could be much larger than those considered here. The center wavelengths (λ_0) for each channel are given in Table 4 in columns 2 and 6 for pre- and post-flight respectively. The maximum error in each measured value for λ_0 is estimated to be ±0.2 nm. It can be seen from the results that both sets of measurements agree within error limits. The pre- and post-flight measurements of the bandwidths are tabled in columns 3 and 7 together with the estimated maximum error in each measurement. The two sets of results agree with each other within error limits in all cases. It is therefore concluded that no irreversible changes occurred in the transmission functions as a result of the flight.

The digital tape recorder produced a good copy of the primary EPROM data set and it will be incorporated in at least one more future Shuttle flight of this payload.

CONCLUSIONS

(i) A sensitive Shuttle GAS payload that is suitable for making optical observations of nighttime terrestrial atmospheric emissions in the nadir and the limb and of Shuttle ram glow has been developed and has completed a successful engineering test flight. The science demands for such a GAS payload should not exceed specific limitations that are characteristic of the GAS carrier. Those limitations are:

(a) a pointing accuracy of no better than ±15°
(b) small data sets
(c) no complex shuttle manoeuvres.

(ii) A functional sealed viewing window assembly with UV transmitting ports has been developed for the experiment.

(iii) The single event temperature observed within the payload after 54.2 hrs of passive flight time on Shuttle was 1°C. This temperature is between 6° and 9° warmer than corresponding flight temperatures in three other non-dissipating GAS payloads.

(iv) No irreversible changes were observed in the instrument transmission functions following the flight.

(v) The Sea Data digital tape recorder worked well as a backup data recording device.

(vi) A reflight of the payload should yield the desired scientific return provided that the difficulties experienced during this flight are not permitted to recur.

(vii) The significance of ground operations in a program of this type should not be underestimated.

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A PAYLOAD FOR INVESTIGATING THE
INFLUENCE OF CONVECTION ON GaAs CRYSTAL GROWTH*

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ABSTRACT

A comparative study of the influence of buoyancy driven fluid flow on gallium arsenide (GaAs) crystal growth has been undertaken. Crystals will be grown from melts with different degrees of convective flow including growth in the microgravity environment of space. The space growth of GaAs will be performed in a GAS payload. A well-insulated growth furnace has been designed for both earth-based and space-based experiments. The self-contained payload will carry two such furnaces in addition to a large battery power source and a microprocessor-based control and data acquisition system for regulating the growth process with high precision. The microcomputer will also monitor the growth conditions and measure and record the acceleration in 3 axes.

INTRODUCTION

The influence of convection on the growth of GaAs crystals is being studied through a series of carefully designed comparative experiments. Gallium arsenide is an important electronic substrate material. It exhibits an intrinsically high electron mobility making it a desirable material for very high-speed signal processing devices, and its direct energy gap makes it a useful material for light emitting devices. Nonetheless, the current GaAs IC yields remain low, the cause being, in part, the presence of inhomogeneities caused by the significant degree of temperature fluctuation at the growth interface. In a gravitational field, density gradients in the melt caused by temperature gradients induce appreciable convection currents which produce pronounced turbulence at the growth interface.

The comparative studies which GTE is performing are being undertaken in an attempt to determine the significance of convection in the generation of these inhomogeneities. To this end, the studies will include growth orientation with respect to gravity, the effect of magnetic fields to restrict convection by increasing the kinematic viscosity of the melt by resisting fluid motion through Lenz's law, and the effect of nearly eliminating the gravity vector altogether. The last set of experiments will, of course, be performed in a GAS experiment aboard Shuttle.

The payload has been designed to carry two identical but isolated growth experiments. The GaAs crystals are one inch in diameter and four inches long and are contained in well-insulated sealed chambers. The experiment cycle begins at launch when the NASA-installed altitude switch activates the power pack and the first of the two completely isolated control systems. Thus, the first crystal growth will take place early in the mission before the battery pack has cooled significantly. Heat dissipated during the experiment will elevate the payload temperature somewhat so the second experiment is planned to be performed about two days later after some cooling has occurred. The second experiment will be activated by an astronaut.

THE PAYLOAD

The payload is illustrated in Figure 1. It is composed of three major elements: the growth furnaces, the electronic control system, and the battery packs.
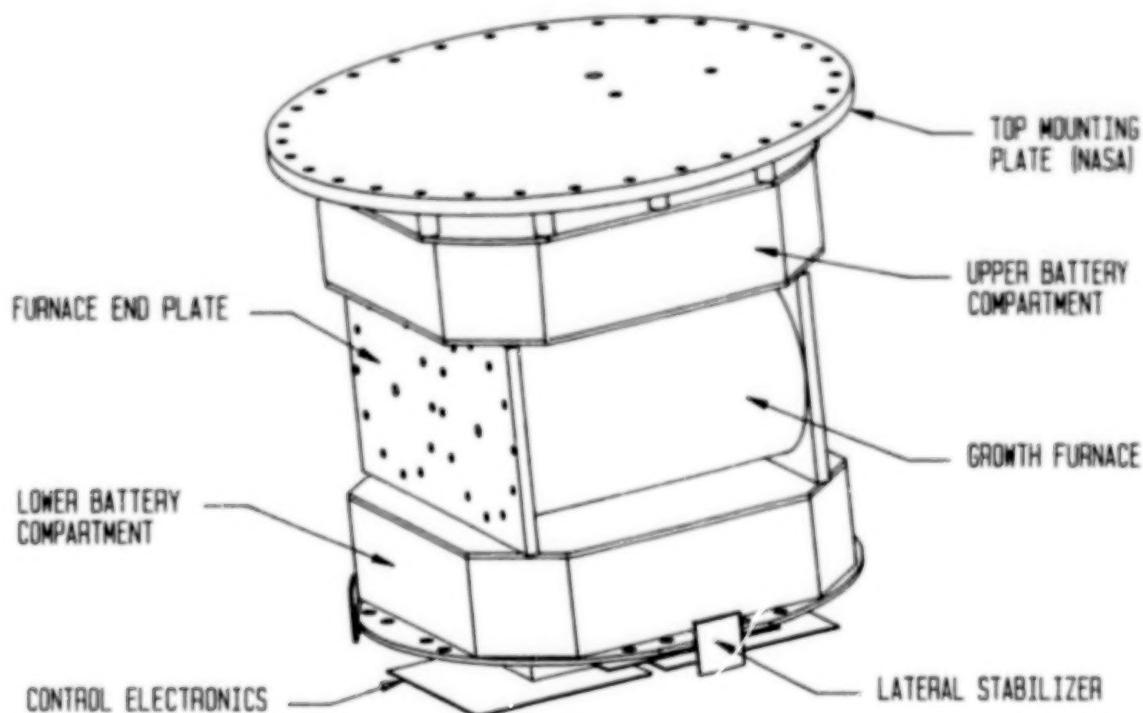
Figure 1. The GaAs Crystal Growth Payload.

The structure is basically that of a stack of inherently rigid boxes, and as such has a moderately high natural frequency. The major weight of the payload is found in the batteries which are enclosed in two separate enclosures, one of which is attached directly to the top plate. The two

growth furnaces are side by side and are installed between the two battery packs primarily for thermal symmetry between the furnaces and the batteries. Since heat is dissipated into the battery packs the batteries should still be warm enough to exhibit good performance during the second experimental cycle which occurs about 2 days after the first. Also for thermal reasons, the electronic controls are located at the bottom of the payload to minimize the effect of furnace heat on the electronic components.

Because the furnaces are sealed to maintain a dry, inert atmosphere, they must be vented overboard. Therefore, the top mounting plate will be provided with NASA's standard "battery box" vents, which explains the spacers from which the upper battery compartment is suspended. The vent lines are provided with additional relief valves to maintain a slightly elevated pressure around the experiment. The lower end plate of the lower battery compartment is circular and nearly fills the diameter of the GAS container to restrict air circulation between the heated growth furnace portion of the payload and the electronic portion. It also provides additional mounting area for the control electronics. Lateral stabilizers are also attached to this plate.

The battery compartments are made of linen-based phenolic sides and type 5052 aluminum end plates. Stainless steel tie rods clamp the end plates together, placing the phenolic side panels in compression.

The two furnaces are enclosed in type 6061 aluminum cylinders which are sealed with type 5083 aluminum heads screwed to the cylinders. O-rings in this joint provide hermetic sealing. Each head is shared by both furnaces resulting in a very rigid but compact assembly.

THE FURNACE

The GaAs boule is at the center of each furnace. Because of the high temperature (1238°C) required for melting and the presence of highly reactive arsenic vapor at that temperature, the boule is sealed within a quartz ampoule. In order to avoid freely floating melt and the accompanying effects of Marangoni convection, a spring loaded piston is also enclosed within the ampoule. The piston is made of graphite and the springs are leaf springs made of boron nitride. These materials were selected because of their high temperature durability and their resistance to the effects of As vapor. These components can be seen in Figure 2, a cross section view of the furnace.

The quartz ampoule is instrumented with several thermocouples sheathed in Inconel and placed within an alumina tube wrapped with platinum heater windings. The windings are graduated in a configuration that produces a nearly linear temperature profile along the GaAs boule so that the melted end is about 60°C hotter than the solid, seed end.

The heater/ampoule assembly is enclosed in rigid fibrous ceramic insulating cylinders. Because of variations in conductivity over temperature, the inner, hence hotter, insulation is yttria-stabilized zirconia optimized for ultra-high temperature applications, while the outer, cooler, insulators are of bonded fibrous alumina. This combination has been found to minimize heat loss. To survive the vibration tests, as well as launch, these rigid but frangible components must be tightly nested within the aluminum enclosure. Zirconia felt is used in the joints to provide a cushion for this purpose as well as to reduce open passageways for additional heat loss.
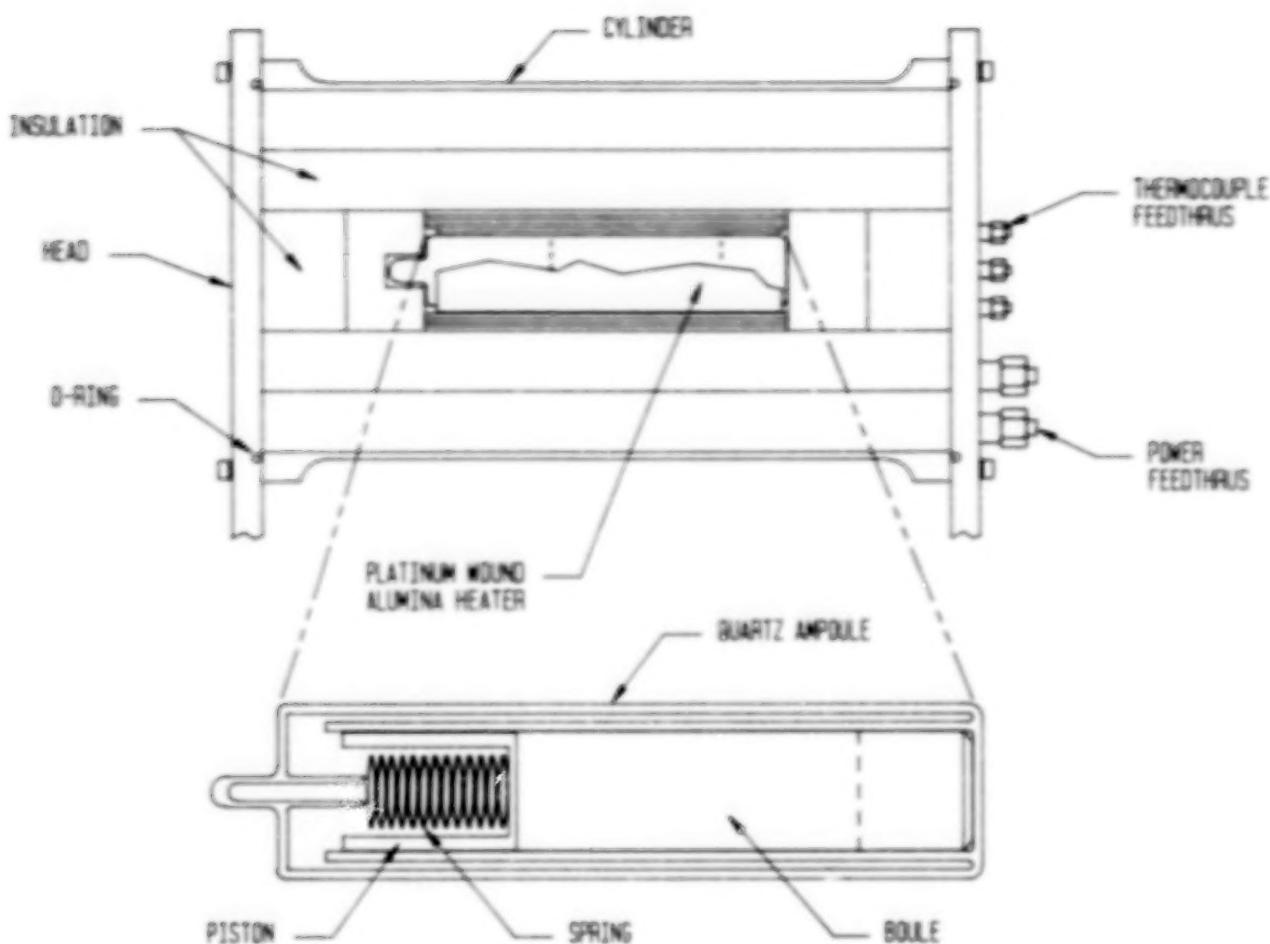
Figure 2. Section View of the GaAs Crystal Growth Furnace.

ELECTRICAL SYSTEM

The electrical system is composed of four major components: The battery power source, the furnace control system, the data acquisition system, and the microacceleration measurement system.

Prime power is derived from an array of 256 alkaline-manganese dioxide cells arranged in a parallel/series configuration to provide 48 volts when fresh. The cell is a size F (MN2300) which we purchase as an assembly of eight cells in a 12-volt lantern battery. After removing the battery case, the semipotted assembly of cells is installed into the urethane foam lined battery compartment. Wires are soldered to the nickel straps already welded to the cells to complete the series connection necessary to develop 48 volts. Each of the eight series strings is wired to a fuse block in one corner of the battery compartment. Thus, each string can be independently checked for continuity and state of charge after the battery compartment is completely closed and secured. Diodes protect a defective string from discharging the good strings. The fuses are installed after all connections are made, verified, and insulated.

Furnace control is accomplished with a microcomputer programmed for the warmup, equilibration, recrystallization and annealing cycles required for good crystal growth. The microcomputer used is a Tattletale IV® which uses a CMOS 6303 microcomputer chip which utilizes an enhanced version of the Motorola 6801 instruction set. It has 11 A/D inputs, 16 digital I/O, and is

programmed in BASIC. Custom signal conditioning circuitry designed at GTE provides thermocouple amplification and ice point compensation using AD595 ICs. The amplified outputs are fed to A/D inputs of the Tattletale. The control thermocouple signal passes through a custom circuit which also expands the 1100°C to 1300°C range for high resolution of the crystal-growing temperature range. Voltage and current through the furnace are similarly monitored using AD202 isolation amplifiers.

The program monitors furnace temperature and battery power every 15 seconds, recalculates a new power level, converts that to a duty factor for the power switching transistor (MOSFET) and outputs this duty factor as a 12-bit serial number. Another custom circuit holds the 12-bit number, converts it to a duty cycle operating at 22 Hz which drives the power MOSFETs through an optical isolator followed by a Schmitt trigger to recover switching speed. The efficiency of this system results in very little power loss, about 1%, and the thermal stability of the furnace is a fraction of a degree. A typical plot of power and temperature is shown in Figure 3.
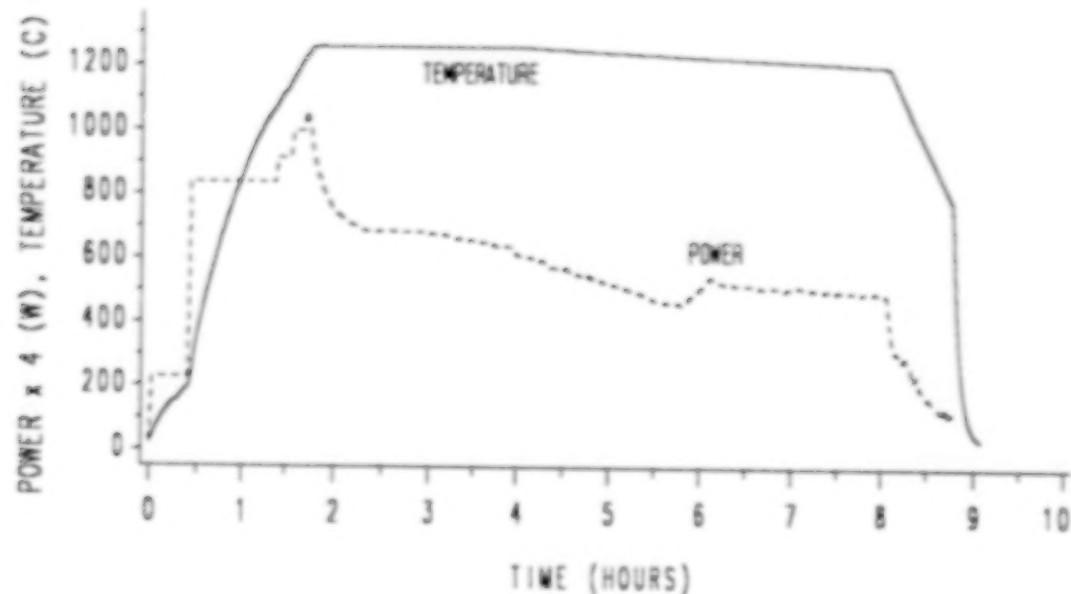
Figure 3. A Typical Experiment Cycle.

The program has been written to include a waiting period at start-up so that the experiment can be scheduled to take place during the astronaut's sleep period when vibration is at a minimum. The time delay will be based on the mission schedule published prior to flight which may, of course, change at the last minute, precluding the most optimal conditions for crystal growth. The program also prevents a subsequent restart in the event of a false trigger pulse.

Data acquisition is largely accomplished by the same microcomputer that is controlling the furnace, and it takes place concurrently with the control program. At each update of the furnace both the control temperature and power level are stored in RAM. Every two minutes a full complement of data including voltage, current, six furnace thermocouple temperatures and one on-board thermistor temperature are stored. At completion of the experiment, data continue to be collected at a slower rate for about two days. Additional data including two more furnace temperatures and several temperature points distributed throughout the payload are recorded by

a second Tattletale. Some of the recorded data are extraneous to the crystal growth experiment per se, but it is stored for future reference and for diagnostic purposes in the event of experiment failure.

Acceleration measurements in three axes will be made throughout the recrystallization period. Three Sundstrand QA2000 accelerometers are mounted orthogonally in a block. These accelerometers have a threshold signal near 10^{-5}g, and our recording range is set to cover from this point to about 10^{-2}g. Each accelerometer is attached to a small circuit card with signal conditioning circuitry and a Tattletale IV mounted in tandem with a 4MAT® memory expansion board. Since the Tattletale cannot measure negative signals, the signal conditioning consists of precision half-wave rectification and inversion of the negative signal so that 2 positive signals can be sent to 2 separate A/D channels. The memory expansion board in combination with the Tattletale provides over 150K bytes of memory for each axis of acceleration. A system malfunction in one axis will not affect data collected from the other two accelerometers.

Altogether, there are 7 Tattletale microcomputers on board: 2 for the 2 separate furnace controls, 2 for supplementary data collection, and 3 for the 3 axes of acceleration.

MODELING

Extensive thermal modeling using NOTHAN, a GTE-written program particularly efficient for nonlinear axisymmetric studies such as this one, was performed for the design of both the payload and the furnace. The furnace was modeled in detail to design the heater winding configuration to establish a nearly linear thermal gradient over the length of the boule. A linear gradient is desirable so that a steadily dropping temperature results in a uniform growth rate of the crystal. This model also was useful in the determination of optimal insulation configuration, selection of temperature monitoring points, and other design details of the ampoule and furnace.

The model was also used to predict overall heating of the payload during an experimental run and the cooling rate of the battery packs subsequent to the run. These data were used to suggest that the second experiment should be performed about 48 hours after the first one begins.

CURRENT STATUS

Presently the payload is nearly complete and could be readied for flight on short notice. Ground-based crystal growth is continuing, and experimental improvements may be incorporated into the payload in the future. Processing through Goddard is in its final stages. It is hoped that a flight opportunity will be available soon after flights are resumed.

ACKNOWLEDGEMENTS

AN ADVANCED MICROCOMPUTER DESIGN FOR PROCESSING
OF SEMICONDUCTOR MATERIALS

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ABSTRACT

In the GAS 330 payload, under development by SSC, two Germanium
samples doped with Gallium will be processed. The aim of the experi-
ments is to create a planar solid/liquid interface, and to study the
breakdown of this interface as the crystal growth rate increases.

For the experiments a gradient furnace has been designed which is
heated by resistive heaters. Cooling is provided by circulating gas
from the atmosphere in the cannister through cooling channels in the
furnace. The temperatures along the sample are measured by Platinum/
Rhodium thermocouples, type S.

The furnace is controlled by a microcomputer system, based upon
the processor 80C88. A data acquisition system is integrated into the
system.

In order to synchronize the different actions in time a multitask
manager is used. Some of the features in the microcomputer system are:

* 16 thermocouple channels
* Digital PID temperature controllers
* Pulse duration modulators for furnace heating/cooling
* 24 analog channels
* Monitor of housekeeping signals
* 1 Mbyte data acquisition system

INTRODUCTION

Since 10 years Sweden has per-
formed materials science experi-
ments in space. The program has
involved repeated participation in
sounding rocket experiments, aero-
plane flights in parabolic trajec-
tory and the preparation of
experiments for long duration
flights. Within the latter cat-
egory three reservations for GAS
experiments have been made. Of
the three payloads associated
with these reservations one is
ready for flight (G-329) and one
is being designed and constructed
(G-330). The experiment for the

third payload (G-541) is not yet
selected.

The G-329 payload contains a
'Space Foundry' for the processing
of 8 kg of lead-tin samples of
different composition. This payload
is described in detail in the
Proceedings of the 1985 GAS Experi-
menter's Symposium and will be
omitted in this presentation.

This paper is instead devoted
to the G-330 experiments on semi-
conductor crystal growth.

In the G-330 the breakdown of
planar solid/liquid interface will
be studied when the growth rate

increases from stable to unstable conditions. The samples to be processed are Germanium rods doped with Gallium. The samples have the dimensions Ø 10 x 110 mm.

The breakdown of a planar solid/liquid interface is important to study both from a theoretical and a practical point of view. The conditions for constitutional supercooling to appear are dependent on the convection, and instability occurs theoretically easier in a non-convection case. On the other hand perturbations are less likely to occur during growth from a melt without convection, which would act in a stabilizing way. These phenomena are best studied in a crystal where interface demarcations are used to study the shape of the solid/liquid interface.

GAS 330: AN ADVANCED GAS PAYLOAD FOR PROCESSING OF SEMICONDUCTOR MATERIALS

Two experiments will be run sequentially in separate furnaces. Each furnace will be equipped with a cooler connected to a common paraffin heatsink, capable of storing the energy generated during the processing of one sample. Each experiment will take approximately two hours to process. Before the second experiment can start, an intermediate period of 10 hours is necessary in order to radiate to space the energy, which has been stored in the heatsink during the first experiment.

Electrically controlled gradient furnace

A furnace will be used, in which the gradient can be controlled by resistive heaters and a gas cooling system, see figure 1. The advantage with such a furnace, is that moving parts that may disturb the micro-gravity condition can be avoided.

The furnace body consists of an Aluminium-Silicate crucible with grooves for the heater wires. The thermocouples are positioned on the inside of the crucible so that a good thermal contact with the sample can be achieved.

For the regulation of the temperature profile in the furnace, it will be possible to use up to
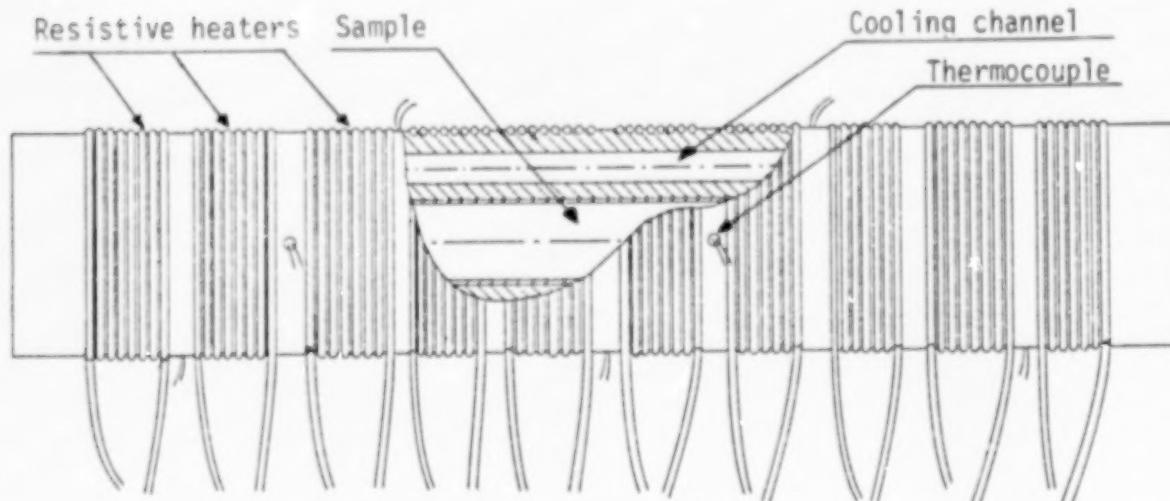
Figure 1. Electrically controlled gradient furnace.

C 2

10 resistive heaters which are individually controlled by digital PID-controllers. The heating elements consist of Kanthal resistance wires.

Cooling gas, taken from the atmosphere inside the GAS cannister, will circulate through cooling channels along the crucible. The cooling channels will be placed between the sample and the heaters. With this arrangement the cooling effect will be distributed along the sample. The cooling gas will be heated on its way along the sample, thereby giving reduced cooling effect towards the hot end of the furnace.

Process sequences

The two experiments will be run through four phases.

In phase one the sample will be heated in an isothermal mode to a temperature approximately $20^{\circ}C$ below the melting point. During this phase the heating power will be slowly increased to avoid thermal stress in the crucible.

In phase two the cooling gas will start to flow and the power to the heaters will be regulated to create the predetermined temperature gradient over the sample. During the establishment of the temperature gradient it is important not to melt the whole sample. If the sample should melt, the result would be a polycrystalline Germanium crystal after the solidification.
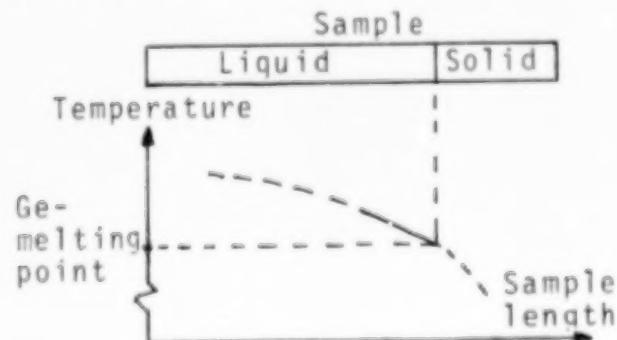
Figure 2. Temperature distribution in the sample.

In phase three the temperature gradient will be stabilized and kept constant in order to homogenize the dopant concentration in the sample, this is illustrated in figure 2.

In phase four the temperature will be lowered and the directional solidification will start. In this type of experiments it is important to have a linear temperature gradient 10-20 mm in front of the solid/liquid interface. The solidification rate for the crystal will be varied in time according to figure 3.
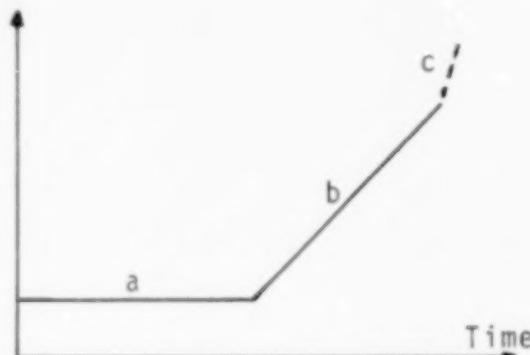
Figure 3. Crystal growth rate.

a. Constant solidification rate.
b. Linear increase of the solidification rate.
c. Maximum solidification rate with all heaters switched off and maximum cooling.

MICROCOMPUTER SYSTEM

The sample processing will be controlled by an 80C88 microprocessor. The same processor will take care of all data acquisition.

The microcomputer system consists of five printed circuit boards: CPU board, analog measurement board, power control board, thermocouple amplifier board and mass storage memory board. (See figure 4).
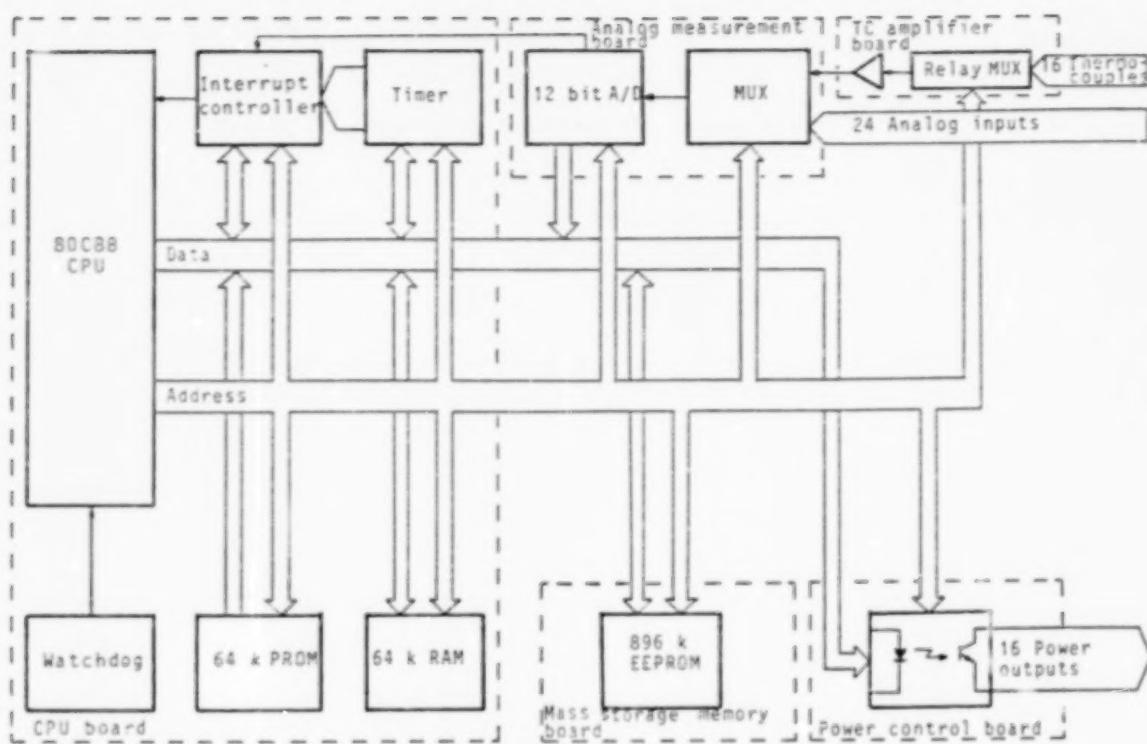
Figure 4. Block diagram.

Processor 80C88

The 80C88 CPU, with 16 bit internal architecture and 8 bit data bus interface, has a direct memory adressing capability of 1 Mbyte. This enables us to integrate the data acquisition system into the control system, since the memory area available for this will be sufficient. A clock frequency of 5 MHz thus gives the system capacity to handle data acqusition, as well as process control.

The CPU board is provided with a 'watchdog' that will reset the system if for some reason the execution is not proceeding as planned. After such a reset or in case of a voltage drop in the power supply, the processor will resume execution from a suitable point in the process. This is achieved by keeping the process status in EEPROMs.

A programmable timer in combination with an interrupt controller makes it possible to create software pulse duration modulators, and a multitask manager that will make the processor switch execution between different tasks at certain intervals. Among the tasks to be implemented is a monitor that will supervise housekeeping signals so that critical conditions in the system can be avoided. Other tasks are thermocouple sampling, A/D conversion, digital PID control, and data storage.

Thermocouple A/D conversion

The most sensitive part of the system is the temperature measurement. Thermocouples, type S, are fixed in the crucible wall of the furnace, giving a voltage level per degree Celsius that is in the μV range. The required relative temperature accuracy (better than $\pm 3°C$) corresponds to a voltage accuracy in the order of 10 μV. This forces us to choose high-

86

stability low-noise components for the temperature measurements. Furthermore, the design of the printed circuit boards becomes delicate. Four-layer boards are used.

The thermocouple signals are multiplexed by relays that introduce a low thermal emf and low dynamic noise, so that the total error stays well below a few microvolts. Up to 16 thermocouple inputs can be connected. An instrumentation amplifier, with gain setting resistors included in the package to reduce temperature drift, amplifies the signal to a suitable level (0-15 V). This signal is fed from the thermocouple amplifier board to the analog measurement board.

The analog measurement board is featured with 25 channels. One of these channels is used for the multiplexed thermocouple signals and the rest of the channels for housekeeping signals. A CMOS multiplexer distributes the selected signal to a 12 bit A/D converter, which supplies the processor with the required input data.

Digital PID controller

An algorithm for a modified digital 'D controller will control the temperature profile along the sample. This means that the formula for the conventional analog PID controller has been adopted and converted by replacing integration with summation, derivation with differentiation and keeping the sampling intervals short. Some of the major shortcomings of the analog PID controller can easily be removed, and motivates the word "modified".

Among the ameliorating features for this application are:

- compensation for nonlinear characteristics of the thermocouples. The registered voltage will be used as an index in a table stored

in memory where the corresponding temperature is kept.

- compensation for integral windup, i.e. removing the overshoot that occurs with an analog controller, due to saturation after large changes of the reference value.

- compensation of controller output, due to other conditions than actual control error.

The power to each heater and to the cooling system is pulse duration modulated. Separate controllers determine the pulse durations. A number of control loops will aim to make the temperature profile follow a preprogrammed temperature sequence.

Pulse duration modulation

The pulse duration modulation is interrupt driven. The timer will supply a system clock signal with a period of 10 ms, which will generate the highest priority interrupt. The interrupt service routine will handle the timesharing between tasks and will clear all power outputs. The time between these clock interrupts can be viewed as split up into two parts, see figure 5. All measurements
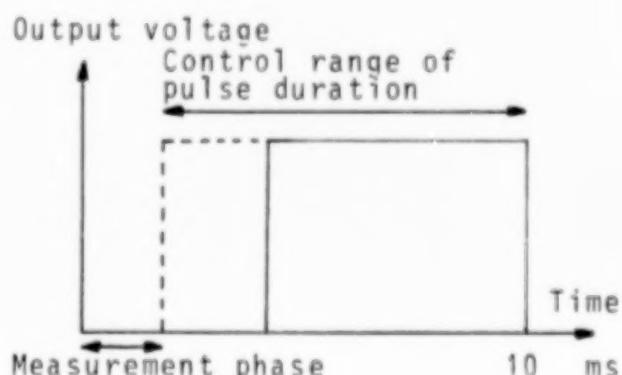
Figure 5. Measurement timing.

take place in the first part, when heater voltage is off. This is necessary to achieve accurate readings. The second part corresponds to the maximum pulse duration allowed.

When the clock interrupt has occurred, the time until the first raising edge of any power output will be set up in the timer. The timer generates another interrupt that will set that specific channel's output high when the specified time has elapsed. The time values will be kept in increasing order in a table stored in memory, so that the output with the longest pulse duration will be switched on first, and the one with the shortest will be switched on last. The next system clock interrupt sets all outputs low and completes one pulse duration modulation period.

The power control board features the output interface to the heaters and cooler. Up to 16 output channels are supplied.

Data storage

The code and data areas for the software take 128 kbytes of the total address space of 1 Mbyte. That leaves 896 kbyte for data storage.

The mass storage memory board is supplied with EEPROM circuits, which enables us to dynamically store various process information supplied by the data storage task. Besides temperatures, the micro-gravity condition will be registered, as well as a certain amount of housekeeping signals such as cannister temperature and pressure.

SUBSYSTEMS

Many of the design concepts used in the first SSC GAS payload (G-329) will be reused in the G-330, i.e. the structure, the thermal control system using a paraffin heatsink and the Lithium

battery system. These systems are described in detail in the proceedings of the 1985 GAS Experimenter's Symposium.

DEVELOPMENT STATUS

The furnace and the microcomputer system have been designed and the software development is going on. The development and construction will continue with the goal to have the G-330 ready for a flight in 1989 if the Space Shuttle flight opportunities permits it.

-APPLICATION OF HOFFMAN MODULATION CONTRAST MICROSCOPY COUPLED WITH THREE-WAVELENGTH TWO-BEAM INTERFEROMETRY TO THE *IN SITU* DIRECT OBSERVATION OF THE GROWTH PROCESS OF A CRYSTAL IN MICROGRAVITY-

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ABSTRACT

Direct visualization of three-dimensional transfer processes of both heat and mass around a growing crystal and mono-molecular growth layers on the surface is possible *in situ* by means of high resolution Hoffman modulation contrast microscopy (HMCM) coupled with three-wavelength two-beam Mach-Zehnder interferometry (TTMI). This *in situ* observation is very suitable for the verification of the growth mechanism of a crystal in a solution or a melt in microgravity.

Crystal growth process.

Crystal growth proceeds when molecules are integrated at the surface *via* the transport of molecules from the bulk solution to the crystal surface, at which latent heat would be released at the same time.

Observation of the crystal surface has been one of the most powerful ways to investigate the integration mechanism of molecules at the surface. This has been achieved by means of special optical microscopies like phase contrast microscopy or electron microscopy using decoration techniques. However, these observations were limited to the crystal which has been taken out of the solution, followed by a special surface treatment. If one could directly observe the movement of mono-molecular growth steps *in situ*, it would contribute to investigation of the fundamental growth mechanism of a crystal in more detail. Based upon this idea!, a high-resolution *in situ* observation method was developed by the author in 1983, although there had been several other *in situ* observations with much less resolution. This made it possible to visualize the movement of mono-molecular growth steps with 1.4 nm height on a crystal growing in aqueous solutions, as shown in fig. 1. This method was recently extended to the growth of a crystal in a solution at elevated temperatures as high as 1800 °K.

The transport of molecules is another important problem which has not fully been understood yet, since very complex convections easily appear near the crystal in gravity, which thus disturbs the transport of molecules. The same holds for the transport mechanism of the latent heat which is released during the growth of the crystal. There have been many attempts to measure the concentration gradient around a growing crystal by the Schlieren method or interferometries. However, the transport of heat has not been measured exactly except in a few experiments, in which they put the array of very thin thermocouples normal to the crystal surface for the measurement. The visualization of the heat transfer around a growing crystal is more difficult and thus few experiments have been performed up to now.

So far, experiments on the transfer problem were carried out in the system in which either heat transfer or mass transfer is negligible, although in actual crystal growth processes, both are important. More interesting is their mutual interactions due to the completely opposite direction of the transfer of the heat and the mass. This is believed, in gravity, to cause complex fluctuating flows near the crystal surface, leading to periodic fluctuation of the growth rate, or periodic impurity incorporation into the crystal. This interaction has not yet been investigated, first because of its complex nature for theory, and second because of lack of a suitable experimental method. Since these phenomena (movement of growth layers and the transport of mass and heat) have the mutual interactions, it would be necessary to investigate all phenomena at the same time by an *in situ* method, because these phenomena are not time-stationary.

Observation in gravity.

Direct observation of both crystal surface and the mass transport phenomena in gravity for the case of aqueous solution growth have been extensively investigated in our group, although heat transfer has not been investigated. The result is summarized as follows.

When the supersaturation is very low, < 0.5%, no convection appears and thus the crystal is surrounded by a diffusion boundary layer, fig. 2a. On increasing the supersaturation, a solutal convection plum starts to develop, fig. 2b, due to the large concentration gradient in the diffusion layer, the critical supersaturation of which is typically 1 - 2%. Since the plum develops intermittently and is unstable, the dispersion of the growth rate of a crystal in this range is very large, ~40%, which would give rise to periodic growth striations even if the bulk supersaturation is accurately controlled, <0.01%. This unstable plum disappears when the supersaturation is increased further, which is followed by the development of a stable plum, fig. 2c. This again stabilizes the growth rate of a crystal. It may be important to note that the supersaturation range, 1 - 2%, is often used to grow large crystals in solutions without considering the hydrodynamical behavior of the convections.

The development of this kind of solutal convection influences not only the growth rate of a crystal versus supersaturation, fig. 3, but also the surface state of a crystal, fig. 4. When the surface of a crystal

which was grown at, for instance 5%, is observed *in situ*, many inclusions are observed to be trapped on the surface. It is interesting to see that they are trapped along the periphery of the root of a convection plumb. As the plum position shifts, the array of inclusions also shifts.

Although this is one of the examples to show that hydrodyynamical properties of the solution around a crystal have many influences on the growth kinetics and the perfection of a crystal, numbers of *in situ* observations have already been performed during the past several years and thus, enough data are available for comparison with the experiments in mocrogravity. It is proposed here to perform similar *in situ* direct observations of a crystal growth process in microgravity, so that one can find out the essential difference between growth mechanisms in gravity and in microgravity in much more direct ways. Such high resolution *in situ* observations as proposed here were developed in Japan for use in gravity, but have not yet been proposed in any countries for use in microgravity. If this kind of *in situ* visualization of the phenomena were performed together with the coupled kinetical measurements, it would have wider applicability in other material sciences in microgravity.

Proposed experiment.

1. Crystal

Several solution-grown or melt-grown crystals will be selected from inorganic and organic crystals; the saturation temperatures and the melting temperatures are 40 - 50 °C. By varying the chemical composition, some crystals are grown as faceted, which are suitable for the direct observation of layer growth on the surface and the mass and heat transport phenomena. The other crystals are grown as dendrites, which are suitable for the visualization of the heat and mass transfer process and the mutual interaction. Needless to say, experiments both in gravity and in microgravity are necessary for the analysis of the growth mechanism.

2. Optical system

Hoffman modulation contrast microscopy (HMCM) with the auto-focusing system is selected among varieties of microscopes because of its high contrast images for both isotropic and anisotropic crystals, by which growth layers as thin as 1 nm can be resolved, fig. 5. In order to visualize the mass and heat transfer process around a growing crystal quantitatively, three-wavelength two-beam Mach-Zehnder interferometry is used (fig. 5). The optical pass and the lenses are almost in common with HMCM. The resolution of the interferometry has much higher resolution than holographic interferometries if it is adjusted correctly. In order to avoid the problem of heat radiation and the electric energy consumption, LEDs with three different colors are used, which are switched on alternatively, in order to increase the S/N ratio of the optical images by reducing the background intensity of the scattering light in a crystal. These are synchronized with the CCD TV camera for recordings. The interference fringes from three different wavelengths and the HMCM images are recorded on video tape.

So as to obtain the three-dimensional information on the heat and mass transfer, two vertically-crossing optical axes will be used.

3. Growth cell.

A crystal is grown in a growth cell, the temperature of which is controlled by thermo-modules with the temperature stability of < 1.0 °C. The cell is made of an aluminum block, fig. 6, in which a degasser is used to remove possible air bubbles in the solution, a solution pump and thermo-modules are installed.

Six growth cells are prepared to be exchanged for the observation of different crystals.

Since a seed crystal is used, a remote monitor is used to see its shape through TV images. This is necessary so as not to dissolve the seed crystal completely just before the growth experiments.

Fig. 1 SPIRAL STEP WITH 1.4 nm HEIGHT OF CdI$_2$ GROWING IN AN AQUEOUS SOLUTION.
BY *IN SITU* OBSERVATION. FROM TV

92
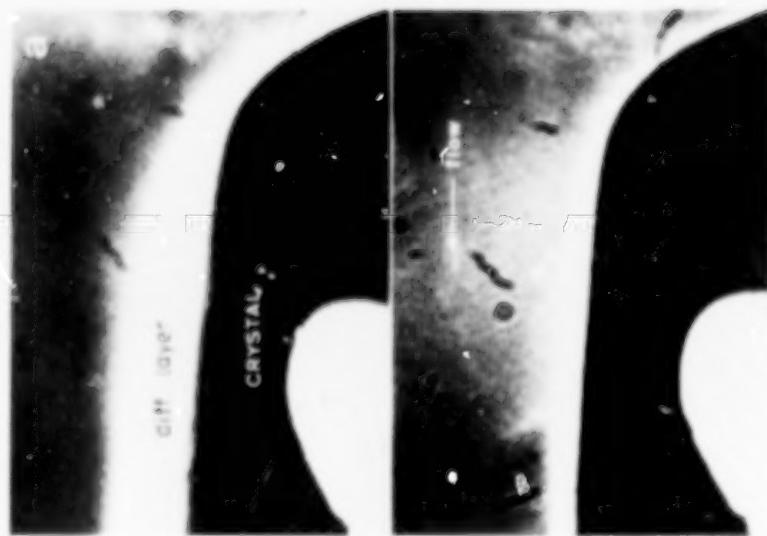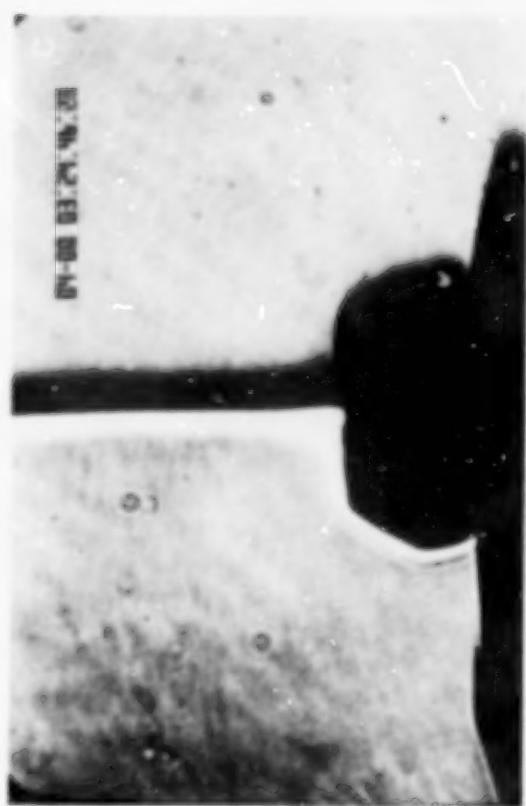
Fig. 2 DEVELOPMENT OF A CONVECTION PLUM
ON INCREASING THE SUPERSATURATION
OF THE SOLUTION. SCHLIEREN IMAGE.
(a) < 0.5%, (b) 2%, and (c) 7%, $Ba(NO_3)_2$
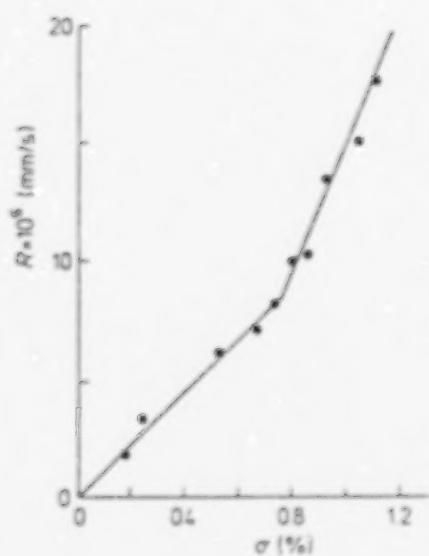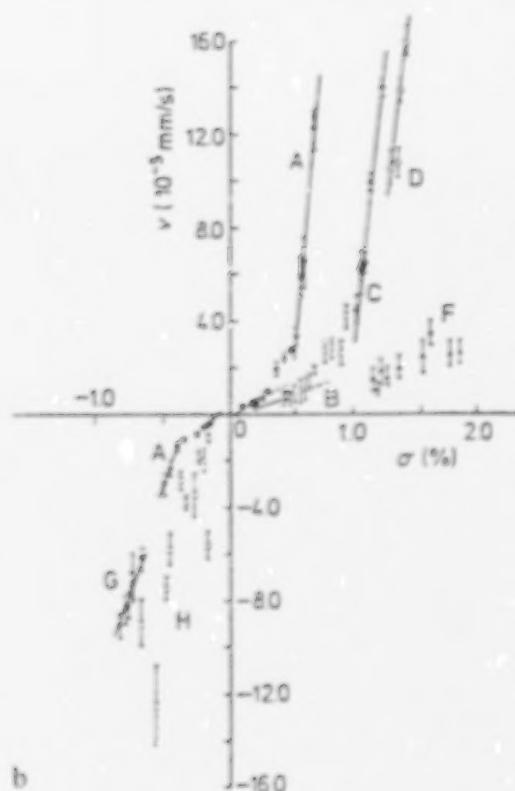
Fig. 3 (a) GROWTH RATE VS SUPERSATURATION, AND (b) ADVANCE RATE OF GROWTH
LAYERS VS SUPERSATURATION, $Ba(NO_3)_2$. NOTE THE LARGER SLOPE WHEN A
PLUM APPEARS.
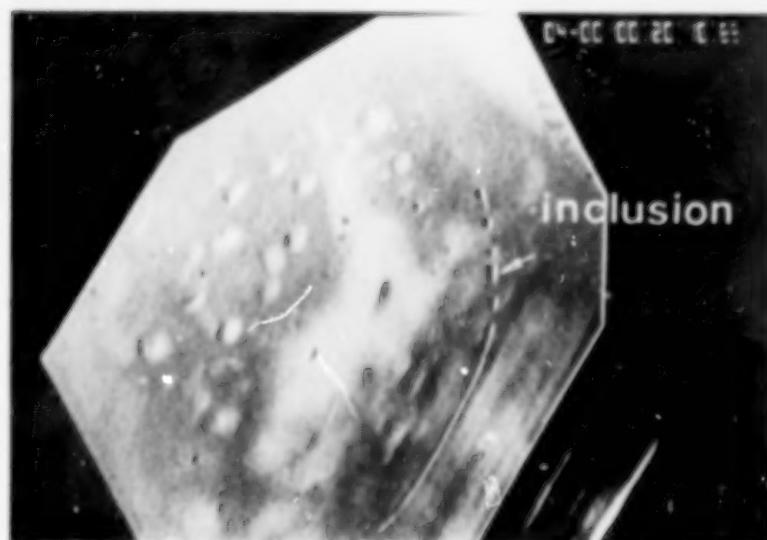
Fig. 4. TRAP OF INCLUSIONS DUE TO THE DEVELOPMENT OF A CONVECTION PLUM. THE
DISTRIBUTION OF THE INCLUSIONS IS LARGELY INFLUENCED BY THE PATTERN OF
A CONVECTION PLUM. THE DEVELOPMENT OF DISLOCATIONS IS ALSO INFLUENCED
BY THE CONVECTION.

94
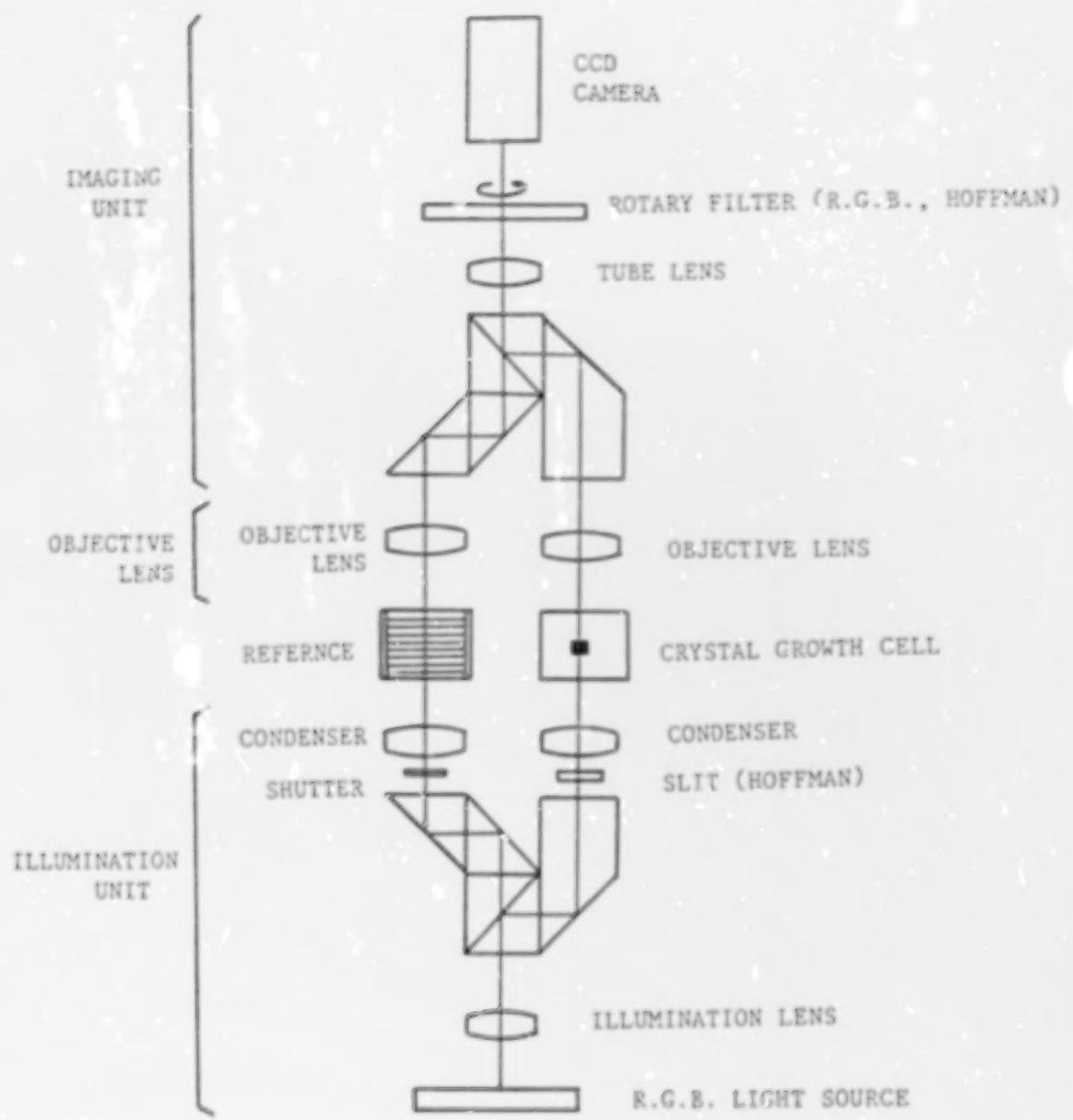
Fig. 5. HOFFMAN MODULATION CONTRAST MICROSCOPY COUPLED WITH THREE-
WAVELENGTH, TWO-BEAM INTERFEROMETRY
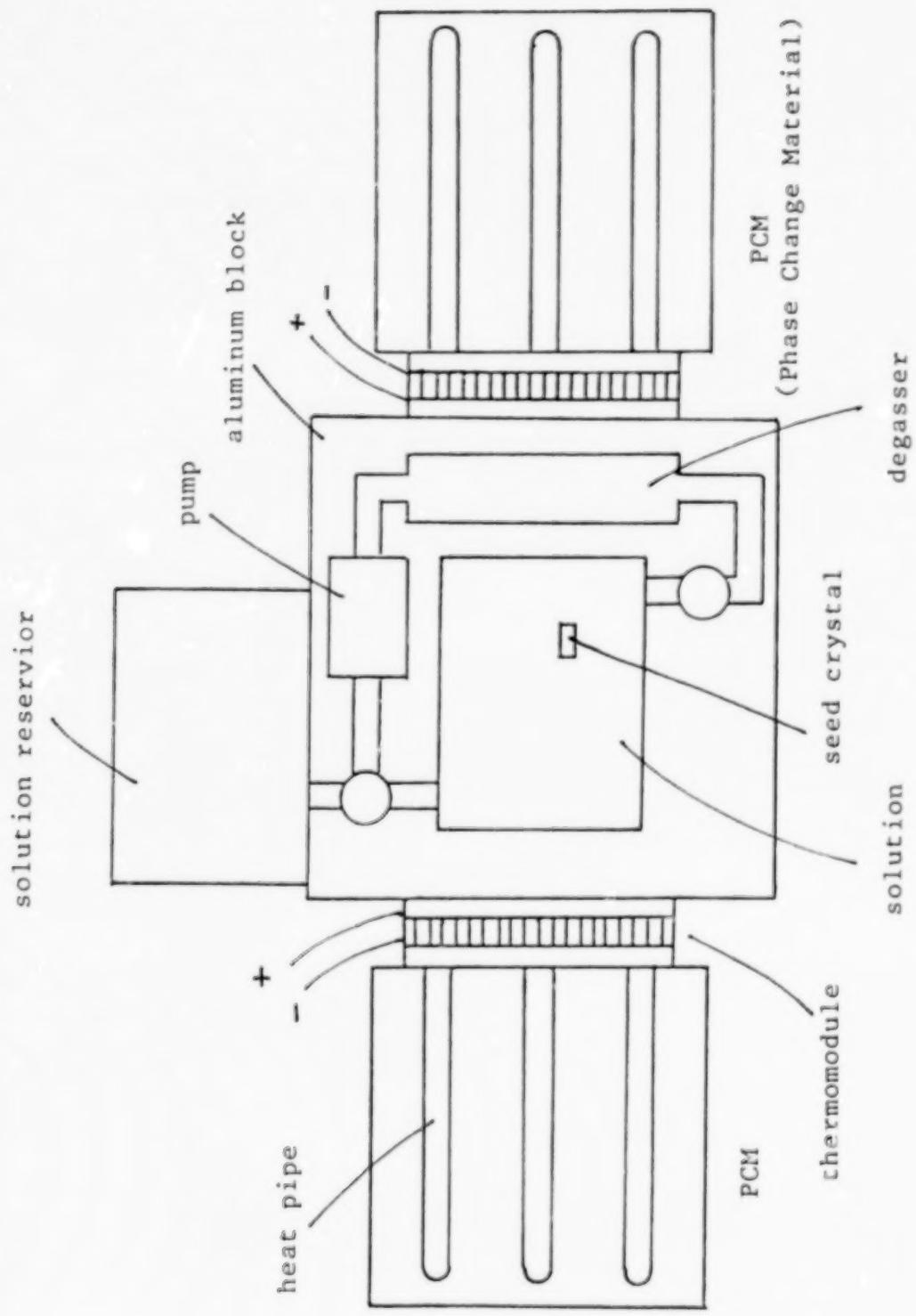
Fig. 6a. THE PRINCIPAL OF THE GROWTH CELL
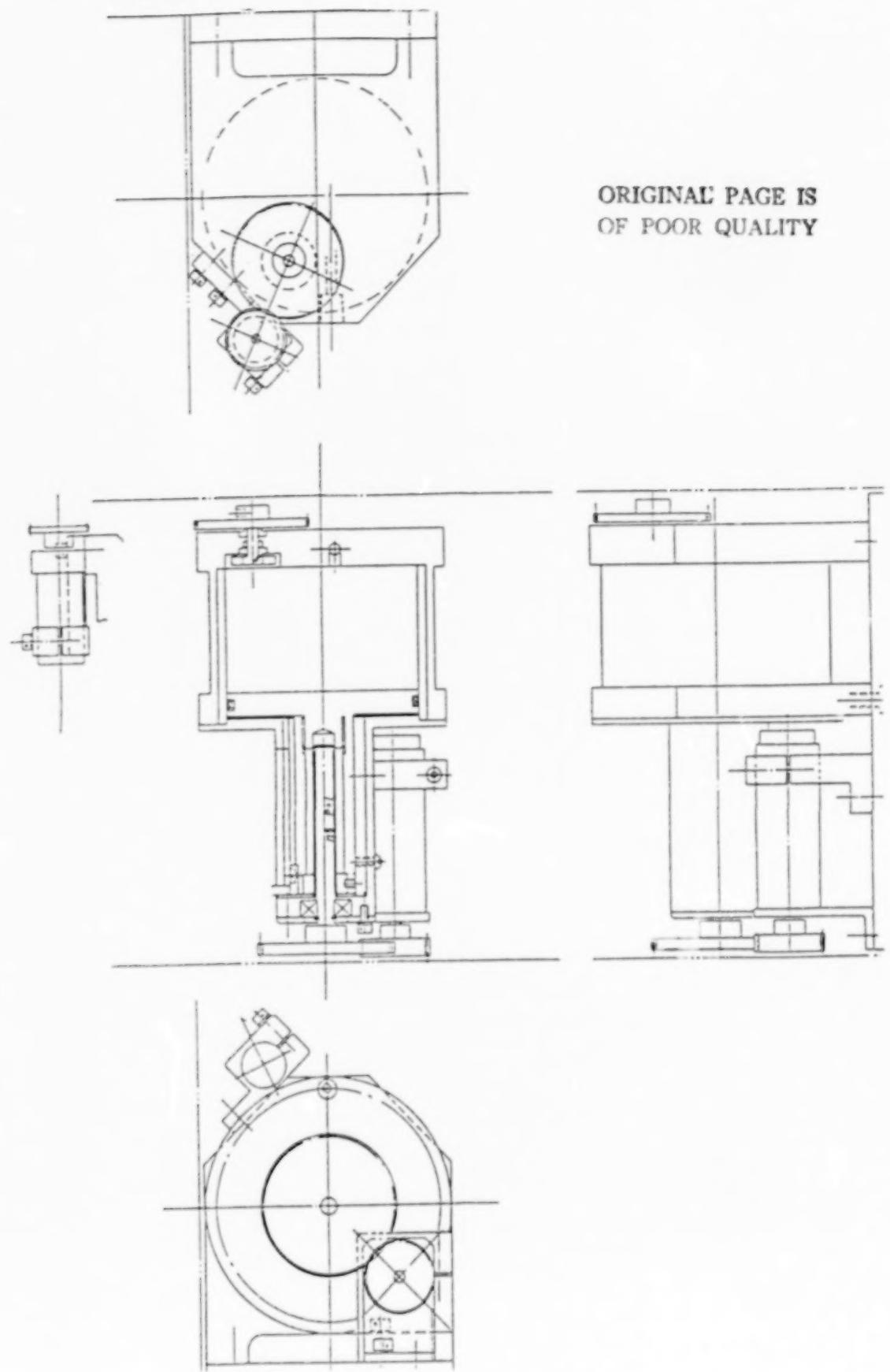
Fig. 6b. THE SOLUTION RESERVOIR, IN WHICH THE SOLUTION IS STORED PRIOR TO THE GROWTH EXPERIMENT

Fig. 6c. THE GROWTH CELL, IN WHICH A SOLUTION PUMP, A DEGASSER, OBSERVATION WINDOWS AND A SEED CRYSTAL ARE INSTALLED

98
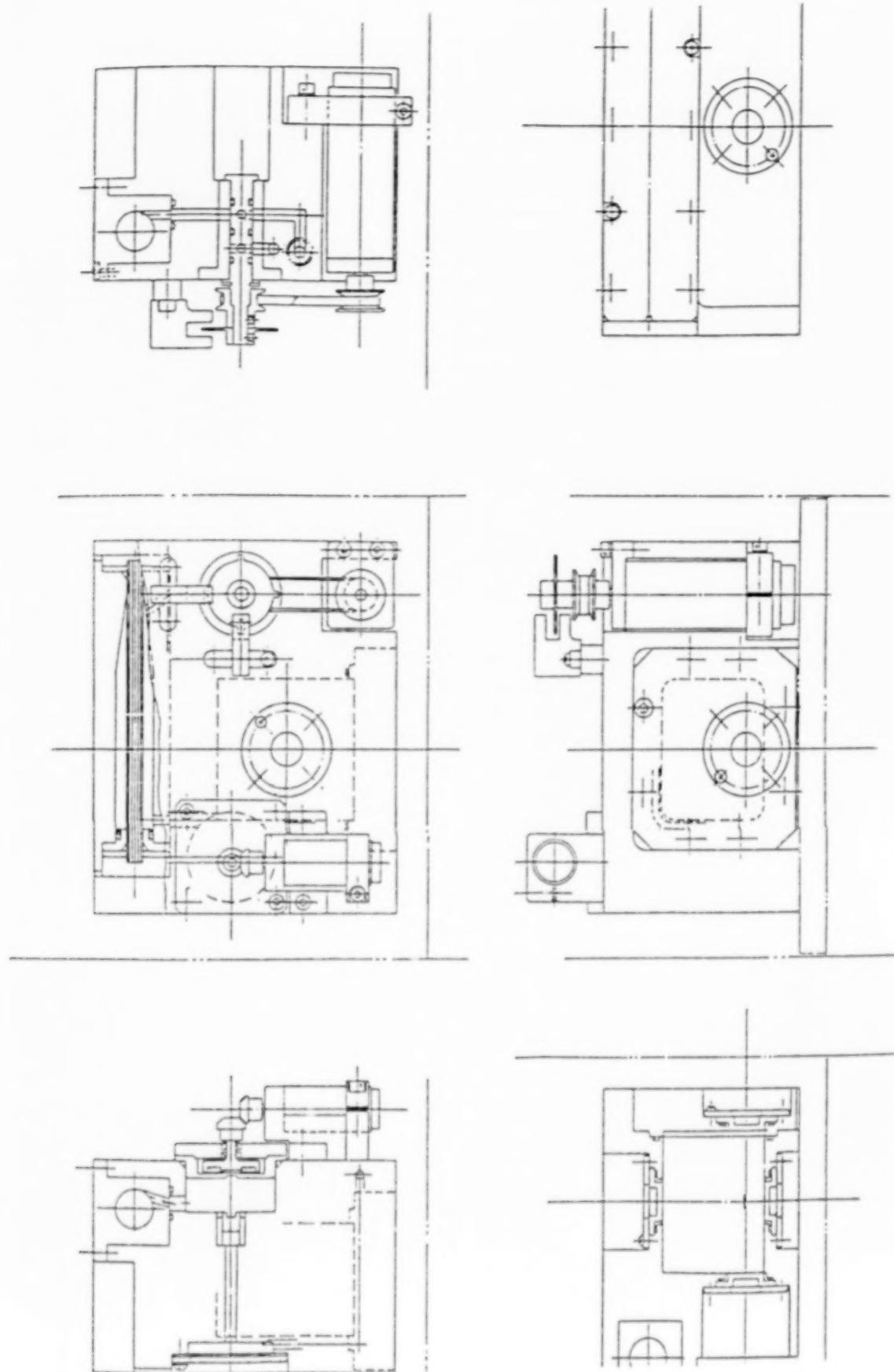
THE CHALLENGE OF G-376

BY
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ABSTRACT

This paper will review the entire G-376 project from history, experiment concept, construction, testing, through post flight data reduction. For each of these topics, one or two specific experiments will be used as an example to develop that topic. Refer to table one for a summary of the 14 experiments.

INTRODUCTION

When G-376 flies it will be no small accomplishment but the result of years of hard work by groups of students, teachers, and sponsors. G-376 is a project begun in 1982 and contains 14 experiments from eleven Maryland public high schools. It is sponsored by Orbital Systems, Ltd., in Lanham, Maryland. The project contains four biological experiments, three microbiological experiments, two materials processing experiments and five physical science experiments. The main power supply is eight lantern batteries equivalent to 128 D cells in 12V and 5V busses. Twelve experiments require power from the main power supply. There are three 35mm cameras. Ten experiments developed their own timing control capability to perform multiple functions at specified intervals. Eight experiments activate their experiment by applying a force to combine two objects separated by a barrier - though each solved the problem differently. This project is a testament to the creativity and ingenuity of today's high school student when a challenge is freely accepted.

The challenge was to design, develop, build and deliver a microgravity experiment. It must be safe, self-contained, and require only power from the can. Each group of students organized itself with a teacher serving as an advisor and decided on a concept for their experiment. It was then up to the group to determine the complexity of their experiment and produce a workable design. They could chose to seek outside help or design and build totally in-house. After a workable design was completed, the groups built and tested and redesigned until it really worked. Even at the time of this paper, the work and testing continues.

HISTORY

Each experiment has a unique and interesting history. The Planaria project's original proposal to examine the effect of microgravity on the regeneration of worms was made by two juniors in the spring of 1982. The working group was formed and began its research in the fall of 1982; fortunately most of the members were freshman and remained active members of the group throughout their four years of high school. The working philosophy of the original Planaria group was to complete the project with a minimal amount of outside help. This resulted in slow progress and much trial-and-error learning but much valuable experience in problem solving.

Because of its ability to regenerate quickly, its hardiness, and the extent of previous study of its regeneration, the Planarian was chosen as the experimental animal. The biggest challenge arose in designing a container in which the Planaria could live. This container had to include an automatic mechanism that would section and preserve the Planaria while in orbit. The early attempts at construction were frustrated by lack of equipment. Experimentation with planarian behavior under varying conditions and maintaining the Planarian cultures over the years provided another struggle. An example of this was the discovery that Planaria pull themselves apart. This realization explained the seemingly random multiplication of planaria in their culture dishes. Another problem was the fierce technical debate that ensued in choosing a method of preserving the Planaria. These challenges taught problem solving and technical planning. The original students learned these lessons and set the foundations for the present group.

ORGANIZATION

None of the experiments could be completed without good organization. One of the more highly organized groups is the Bacteriophage experiment. In order to produce the Bacteriophage experiment, teachers and students have been recruited every year. More than twenty teachers and one hundred four students have been involved in this one project since 1982. Recruitment of the students occurs yearly in grades nine through twelve. Slide presentations, displays, and showcases advertise the project. Students who are interested in the project are asked to read press releases and information about the project. This yearly recruitment of students helps ensure the continuity of the project. The older members inform the new members of the methods and procedures required to produce the project.

The project is divided into specific areas. These include the following: manufacturing, public relations, displays, electronics, report writing, drafting, printing, art, and photography. Students may select the area in which they are most interested. Students who are not interested in the scientific aspects of the project may become involved in the club's fund-raising activities which support the financial needs of the project. The funds raised purchase raw materials for manufacturing, film, display materials, and other essentials. Members of the club are identified by a logo button developed by the art department. The club distributes these buttons to members who have actively participated in the project's success.

Teachers from all departments in the school are recruited by the coordinators and students. Students must explain the project to the teachers and enlist their help with specific problems.

Successful coordination of the Bacteriophage project requires approximately two hours of work every day by the sponsors and students. Students working on different aspects of the project such as public relations, photography, etc., assemble as an entire group to present general updates of information. The separate divisions also meet with teachers who are expert in their specific fields. This collaboration insures the continued progress and continuity of all aspects of the project.

Presentations of the project have been given to the Parent Teacher Student Association, Prince George's County Board of Education, civic groups, NASA as well as other schools. Students are also given special recognition at the school's annual awards program.

Future plans for the Bacteriophage group are formulated each spring for the coming school year. Some of these include manufacturing of mockups for testing and displays, continued recruitment of students, computer training, analysis of space related scientific articles, and scheduling of future presentations.

EXPERIMENT CONCEPT

The development of the experiment concept into a workable design is the first major step of the process. The Nematode project is unique in that it has not been done in any previous flights. The project proposes to examine the rate of growth of the Nematode, a small worm called Caenerhabditis elegans. The experiment takes Nematodes in a dormant stage, allows them to grow and then fixes them at different life stages. The returned samples will be taken to a laboratory and the growth rates will be compared to a ground control group. The factors to consider include male to female ratio, birth defects, and effects of cosmic and electromagnetic radiation in the space environment. A critical factor in this experiment is maintaining the proper environment for the Nematodes from the time they are sealed at the launch site until they are returned to the school after the flight.

The design of the Nematode experiment has to accomplish all of these objectives to return useful data. The essential design of the experiment includes an Aluminum box container, a block of solid plastic separated into two halves from which the chambers are drilled, an electronics box, and a phase change heat cell to maintain temperature requirements. The chamber block, constructed from two slabs of Lexan plastic, contains two redundant sets of ten chambers. Each of the twenty chambers consists of the growth segment, where approximately 100 Nematodes are stored, a food housing and a fixative housing which are separated from the growth segment by small glass dimple actuators which shatter upon command from the controller circuit. All of the food actuators fire sequentially when the experiment is activated and the fixative actuators fire at timed intervals.

101

Over the past four years, there have been several changes in the design. Some of the problems encountered in earlier models include: material strength problems with the plastic used, displacement of air in the chambers, leakage from vibrations and the controls for the safe initiation of the dimple actuators. The present design has two blocks of Lexan glued together to prevent leakage and is strong enough to meet the structural requirements. The control circuit insures the dimple actuators to be safe and efficiently uses power by sequencing the firing of the food releasing actuators instead of firing them simultaneously. The phase change heat cell, containing calcium chloride hexahydrate and bisol II will keep the Nematodes within the temperature limits.

Preparing the Nematodes for flight will take several months immediately before launch. The Nematodes all have to be in the same life stage prior to injection into the experiment and they also must be capable of being dormant for several weeks.

The Protein Production of bacteria experiment has the same two stage operation as the Nematode experiment. The bacteria begins in a freeze dried state in the center section of two ALCAR plastic bags. To one side, separated by a barrier, is the food. On the other side is the fixative. This experiment uses two stepper motors to release the barriers when the controller circuit actuates the mechanism. The Protein Production experiment requires strict temperature limits (37 +10 degrees C) during the mission so it contains a thermostatically controlled heater.

CONSTRUCTION

Hardware for G-376 has been constructed in every imaginable place from basements to school classrooms to government institutions to private shops and laboratories. The biological experiments developed techniques to incorporate sterile material into their projects before launch. Experiments constructed in-house showed the student's methods of hardware construction.

The Radish Seed experiment was constructed by students in a machine shop. The experiment expects to photograph the germination of seeds in microgravity. When the experiment is activated, the seeds have to be injected into the growth chamber. To do this the students devised a solenoid driven plunger assembly consisting of ten rods which have seeds at the end. The force of the solenoid drives the seeds through a thin plastic shield into the growth medium while the solenoid pulls its own power plug. Hours of machining was required to create a leakproof container and a low friction sliding mechanism that withstands the force of the solenoid.

The Solid Foam experiment combines polymeric methylene diphenyl isocyanate with freon in a polyol solution to produce a solid structure. The entire experiment was constructed in-house. The two liquids, contained in syringes, are released by a motor driven push-plate and injected into a chamber where they combine to form the foam. But the liquids have to be mixed thoroughly or the foam will not be uniform. After several failures, a block of plastic was drilled out to allow the liquids to flow together for several centimeters before reaching the chamber. The difficult part was insuring that the mixing chamber would not impede the flow or leak - either of which would effectively ruin the experiment.

TESTING

Designing an experiment and buiding it does not complete the process. It has to be tested to insure that it will work as planned. For most of the experiments there was more time spent testing and redesigning than designing and building. The Polyethylene melt experiment is a good example of this idea. This experiment wants to examine the structure of Polyethylene plastic melted in space. Polyethylene melts at 163 degrees C. First an efficient heating method had to be designed to minimized power. The final design is an Aluminum container with two cylindrical heating coils to melt the various shapes of Polyethylene packed inside the container. The various Polyethylene shapes maximize the surface area for faster melting. A problem that only testing could fix was the amount of power required to melt the plastic and a method of turning off that power after the experiment was finished or a failure occurred. A 12V, 16 D cell power supply was found to melt the Polyethylene in less than two hours. The redundant power cutoff system uses three independent methods: a thermostat cutoff switch, a timer circuit and a second thermal switch made of Polyethylene that opens when the plastic melts. Overheating of the can was overcome in the laboratory by using enough insulation.

The Liesegang Bands experiment will photograph the reaction of potassium chromate and copper acetate in agar. All testing was done in-house. The chemical testing was carried out in two phases. First a suitable gel had to be found. Gels such as sodium silicate, unflavored gelatin, and agar were observed as they were subjected to freezing and temperatures around 200 degrees F. They were alternately subjected to the temperature extremes for periods varying from several hours to several days. The agar appeared to show the least responses to such temperature variations.

The reacting chemicals were selected after the best gel was found. Several chemical combinations, such as potassium chromate and copper acetate, potassium chromate and silver nitrate, lead acetate and potassium iodide, cobalt nitrate and ammonium hydroxide, were tested and their crystal formation evaluated and photographed. The combination of potassium chromate and copper acetate was selected because of the formation of brown crystals that contrasted well with the color of the agar containing the chromate. This combination photographed well.

Potassium chromate and copper acetate were allowed to react under varying temperature conditions and maintained in the laboratory for as long as two montns. The crystals held up well under temperature variations, and for as long as two months.

Mechanical testing of the injecting mechanism involved a variety of procedures including solenoids, plastic and glass tubes, and plastic and glass syringes. Plastic syringes were selected because they had better flow characteristics than ground glass syringes. Glass tubes were chosen because of better transparency leading to better photographs.

Photographic testing became the major problem with the Liesegang Band experiment. The original placement of the flash attachment blocked the view of the Surface Tension experiment which is to be mounted above the Liesegang Band tubes. Both experiments will be photographed by the same camera. The light intensity of the next flash attachment bleached out all pictures. At the present time, it is felt that a ring flash, with the bottom and sides covered with tape so the light can be bounced off of the top of the experiment, will be an acceptable light source. Testing continues.

POST FLIGHT

For most experiments, most of the work is completed when the can is sealed for launch. But for some, the work does not begin until after the experiment is returned.

Once the Cosmic Ray project has been returned to the school, the process of data reduction - collecting, interpreting, comparing, and concluding - begins. The Cosmic Ray project utilized a special plastic - allyl diglycol polycarbonate or CR-39 - to collect a record of high energy ionized particles which pass through the plastic at a range of 8 to 30 MeV/amu (those of higher energy cannot be detected by CR-39). The CR-39 will be arranged into two blocks of fifty sheets - each sheet being 20 microns thick - per block. The two blocks will be placed in areas of minimum shielding to maximize exposure to cosmic rays. The blocks are made of .25 inch Lexan, thinned to .125 inches in the center to reduce absorption of cosmic rays through the block. The cosmic rays which pass through the plastic leave a weak spot or track in each sheet through which they pass. Thus a permanent record of the cosmic rays is made.

To uncover this record the CR-39 sheets, numbered for identification, are exposed to 6.25M NaOH at 70 degrees C. The sheets are removed from the hot NaOH before the CR-39 is totally dissolved, thus more plastic is dissolved in the weak spots or tracks where the cosmic rays have passed. With the help of high power microscopes and computers, the width, depth, angle, and shape of a cosmic ray track can be measured. These computers will also help in analyzing the four measurements by comparing the data with reliable data from other similar experiments. This will help to determine the origin, type, and velocity of each recorded cosmic ray. These results are used to study the composition of the sun and possibly solar flares as well as stellar bodies, new cosmic rays, and the space environment. Finally, the data will be compared to other cosmic ray experiments to determine the validity of the work and to draw conclusions.

CONCLUSION

This paper has presented the process by which each of the fourteen projects advanced from abstract ideas into a workable microgravity experim. All of the experiments in the G-376 program were conceived, designed, buil and tested either by students directly or with students involved.

TABLE ONE: EXPERIMENT SUMMARY

EXPERIMENT	SCHOOL	TYPE	DATA METHOD
Gene Jumping	Friendly	Microbiological	Returned samples
Radish Seeds	Bowie	Biological	Photographs
Liesegang Bands	Oxon Hill	Science	Photographs
Surface Tension	Oxon Hill	Science	Photographs
Cosmic Ray	Roosevelt	Science	Returned samples
Nematode	Roosevelt	Biological	Returned samples
Bacteriophage	Suitland	Microbiological	Returned samples
Protein Production	B-CC	Microbiological	Returned samples
Planaria	Blair	Biological	Returned samples
Capillary Action	Blair	Science	Memory chip
Immiscible Liquids	Gaithersburg	Science	Memory chip
Polyethylene Melt	Seneca Valley	Material Processing	Returned samples
Solid Foam	Thomas Wooton	Material Processing	Returned samples
Brine Shrimp	Thomas Wooton	Biological	Returned samples

Drosophila Geotaxis as a Tool for the Study of Aging

by

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Abstract

Age-dependent changes in geotaxis profiles have been examined in 27 wild-type populations of Drosophila, representing a diversity of species (16), semispecies (4) and strains (7). In addition, four strains of D. melanogaster (two strains selected for postponed senescence and increased lifespan, and two control strains) have been tested. Tests were carried out at a minimum of three test ages, and involve the use of a calibrated, adjustable inclined plane that can be set at any angle between 0° and 85°. Among selected lines, decline in geotactic response occurs later in the long-lived flies than in the controls (28 days vs. 14 days). Longer-lived flies continue to show an increase in negative geotactic response through age 14-days. These results suggest that common processes may be influencing the rate of decline in geotactic response and longevity. Further analysis of the mechanisms underling age-dependent changes in geotaxis may reveal factors which influence the aging process itself. The use of geotaxis aging markers in a broad range of Drosophila species reflecting varying degrees of genetic relatedness is proposed to test the universality vs. specificity of aging processes.

Introduction

Drosophila orientation to gravity, i.e., geotaxis, has been a valuable experimental system for addressing a broad range of questions concerning the aging process. As summarized in an earlier communication (Schnebel et al., 1986), age-dependent changes in geotactic response have provided biological markers for identifying senescent individuals, examining environmental effects on aging individuals, determining the physiological basis of behavioral decline, localizing age-dependent changes at the cellular and molecular levels that accompany such behavioral decline, and identifying genetic mutants which alter aging patterns (Herman et al., 1971; Miquel et al., 1976; 1979; Leffelaar and

Grigliatti, 1984a, b).

Recently, Johnson (1987) has shown that processes which contribute to aging can potentially be identified using behavioral markers in genetically manipulated strains of nematodes exhibiting differences in lifespan. Since Drosophila lifespan can also be altered by genetic selection (Luckinbill et al., 1984; Rose, 1984; Hoffmann and Grossfield, unpublished data), Drosophila geotaxis provides an appropriate behavioral system for similar investigations of aging processes.

Additionally, the question of whether "aging hypotheses" derived from genetically selected strains apply to other taxa, can be easily tested using the array of strains and species representing different degrees of genetic relatedness present in the genus Drosophila.

Materials and Methods

Animals and Housing

Twenty seven Drosophila populations representing a diversity of species (16), semispecies (4) and strains (7) were tested for age-dependent changes in geotactic response (for details, see Schnebel et al., 1986). Flies were housed at 19-20°C, 67-70%RH and constant light, and maintained on a raisin-based culture medium. In addition, four new strains of D. melanogaster (obtained from Dr. Robert Arking: Wayne State University) were also used in geotaxis experiments after undergoing special selection regimes for postponed senescence and increased lifespan (two selected strains and two control strains). These strains were maintained at 25°C and 60-70%RH.

Genetic Selection Procedures

Selection protocols followed those of Luckinbill et al. (1984). Through these procedures, two long-lived strains: NLA and NLB (NL designates non-density controlled, late-reproducing lines), and two control strains: RA and RB (R designates random, unselected control lines) were produced.

Geotaxis Experiments

Tests on the twenty seven populations of Drosophila followed procedures described in Schnebel et al. (1986). Briefly, flies aged 1-2 days, 7-9 days and 30-36 days were tested in glass tubes resting on an inclined plane that could be set at any angle between 0° and 85°. The number of flies in the upper and lower halves of the tube was recorded at each angle. Data reveal the minimum angle required to elicit a geotactic response (geotactic sensitivity), directional tendencies at all angles, and patterns of age-dependent loss of geotactic response.

Procedures for testing the four strains of D. melanogaster that underwent different selection regimes were modified as follows: Three hundred virgins of each sex were collected for each strain and tested separately. Thus, eight

groups of flies were tested for a total of 2400 flies. Groups: NLAm, NLAf, NLBm, NLBf, RAm, RAf, RBm, RBf. Flies were maintained in groups of 20/vial and transferred to fresh food vials three times/week. At the time of transfer, the number of dead and escaping flies was recorded. For each of the eight groups, ten numbered vials (200 flies) were used for housing experimental flies, while the remaining 100 individuals were maintained to replace any lost flies before experiments. Experimental vials were chosen randomly each day using numbers provided by a computerized random number generator.

Flies from the eight groups were tested on the day of eclosion (day 0) and on days 3, 7, 14, 21, 28, 35, 42, 49, 56 and 63 post eclosion. On each test day, two vials of each sex and strain were tested. The twenty flies from each test vial were transferred to a 30cm glass tube under light carbon dioxide anesthesia. Flies were set aside for a minimum of 30min before testing on the inclined plane. Ali tests were done in a "dark" chamber where the only light source was a flashlight covered with both uv and red filters. Recorded light levels during testing measured 0.22-0.28 footcandles. Flies were tested for geotactic response at angles ranging from 0° to 80°, and at three different orders of presentation (increasing angles: 0° to 80°; decreasing angles: 80° to 0°; and random presentation of angles). For testing, flies were dislodged to the bottom of the tube and the flashlight turned off before raising the board to a test angle. After 1min at the test angle, the flashlight was turned on and the number of flies in each half of the tube was recorded. Testing was done at normal rearing temperature and relative humidity.

Results were plotted as Gt values (Bean, 1977; Schnebel et al., 1986). This value can range from -1 to +1, where -1 indicates that for a specific angle, all flies are observed in the top half of the tube (negative geotaxis reflects movement away from the force of gravity). Conversely, a value of +1 results if all flies are in the bottom half of the tube. For preliminary analyses, results from each order of presentation of angles were pooled to provide mean Gt values at all test angles for each strain, sex and age.

Results and Discussion

Fig.1a compares geotactic responses in long-lived females (strain NLBf: LT50 = 52 days) and control females (strain RBf: LT50 = 45 days) at three test ages (0 days, 3 days, 14 days). Both strains show a similar increase in negative geotactic response through the first two test ages. However, by the third test age, RBf flies show a significant decline in response (paired t-test of Gt values at 3-days vs. 14-days: t = -2.828, p < 0.025), whereas the longer-lived NLBf flies become significantly more negatively geotactic (paired t-test of Gt values at 3-days vs. 14-days: t= 4.027, p < 0.005). Not only does negative geotactic response in the long-lived strain decline at a later age (28 days, not shown), but they continue to show an increase in negative geotaxis through age 14-days (the age at which the control strain has already shown a decline). Johnson (1987)

Fig 1a. Geotactic profiles of long-lived females (NLBf) and control females (RBf) at three test ages (0 days, 3 days, 14 days).
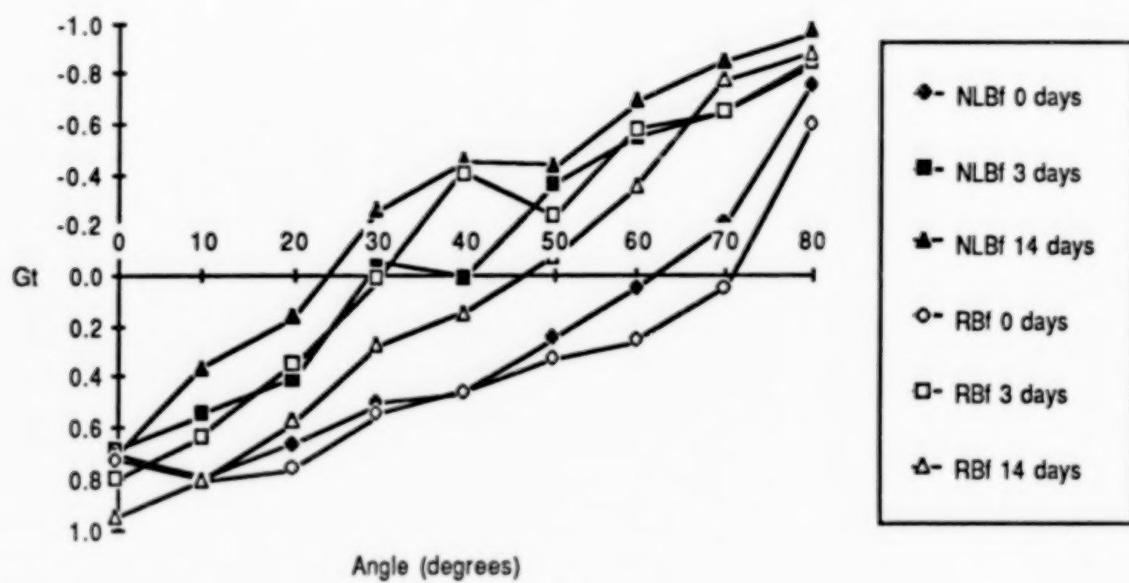
Fig. 1b. Geotactic profiles of long-lived females and males (NLBf and NLBm) vs. those of control females and males (RBf and RBm) at age 14 days.
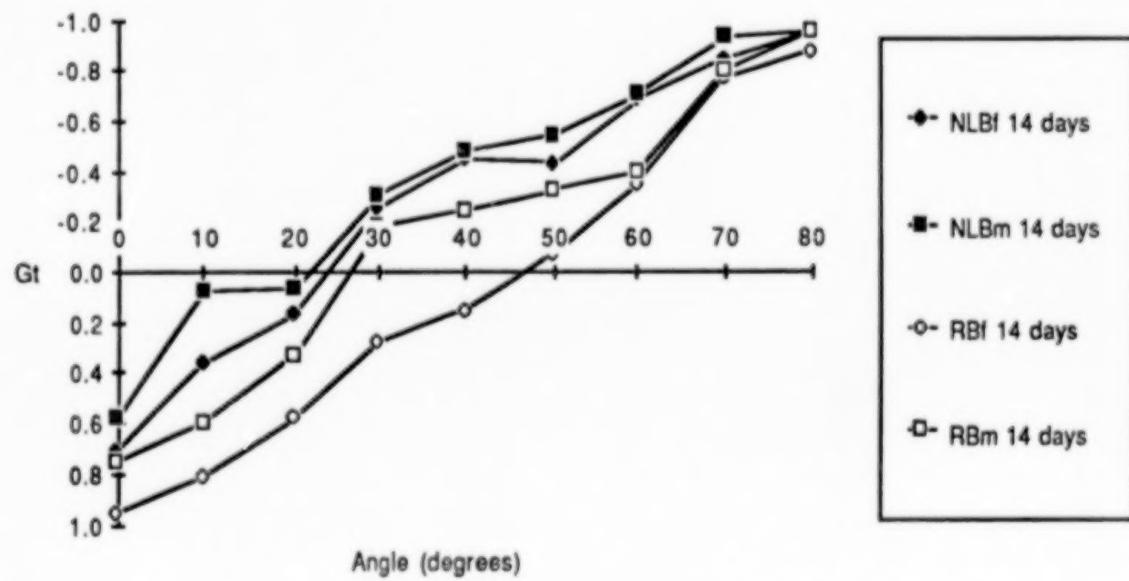
suggests that the key criterion for choosing appropriate biomarkers of aging is to demonstrate that manipulations which prolong life also slow processes displaying age-related functional changes. He also suggests that when time of loss of function in a behavioral/physiological system covaries with lifespan, the two phenotypes may be specified by a common process or processes. Since geotactic response declines more slowly in the long-lived strain than in the short-lived control, common processes may be influencing the rate of decline in geotaxis and longevity. Similarly, comparisons of individuals with prolonged (NLBf) vs. "normal" (RBf) development of geotactic response, may ultimately reveal factors that affect the rate-determining processes which influence aging differences between those individuals.

Fig.1b shows that at the age where strain differences become apparent (day-14), long-lived males and females are more strongly negatively geotactic than control males and females. However, differences are most significant between females of the two strains (paired t-test of Gt values of NLBf vs. RBf: t= -5.592, p < 0.0005; NLBm vs. RBm: t= -4.072, p < 0.005), suggesting the use of females for the more detailed analyses of behavioral/physiological decline.

Figs. 2a (age: 1-2 days) and 2b (age: 7-9 days) compare the geotactic responses of five closely related strains and species of the D. melanogaster species group. These strains and species were maintained under identical conditions without any selection regime for lifespan. Each population has a similar negative geotactic response at the earlier test age. Yet, differences in the age-dependent patterns of change become evident at the older test age based on the following criterion: The angle at which the number of flies in the top half of the tube becomes significantly greater (Chi-square test) than the number of flies in the bottom half can be used as a measure of geotactic sensitivity (the smaller the angle necessary to elicit a significant geotactic response, the greater the geotactic sensitivity). The "critical angles" at the first/second test ages for each population are as follows: simulans-G: $15^{\circ}/10^{\circ}$, indicating a slight increase in sensitivity; mel-F: $20^{\circ}/25^{\circ}$ and ananassae: $10^{\circ}/15^{\circ}$, indicating slight decreases in sensitivity; mel+/+: $15^{\circ}/65^{\circ}$, indicating a large decrease in sensitivity; simulans: $10^{\circ}/$none, indicating a decline in sensitivity to the extent that there is no longer a significant difference between the number of flies at the top and bottom of the tube at the second age. If the rate of loss in geotactic response can be correlated with differences in lifespan among these test populations, this would support the ideas that a) decline in geotaxis and decline in longevity may share some common causal process, and b) this process need not be specific to genetically manipulated populations, but instead, may be more universal. Such comparisons could be extended to different Drosophila species of varying degrees of genetic relatedness. This type of approach may reveal whether factors which influence aging and senescent decline in geotactic function are shared across taxa.

Fig.2a. Geotactic profiles of closely related strains in the D. melanogaster species group (Age:1-2 days).

Angle (degrees)
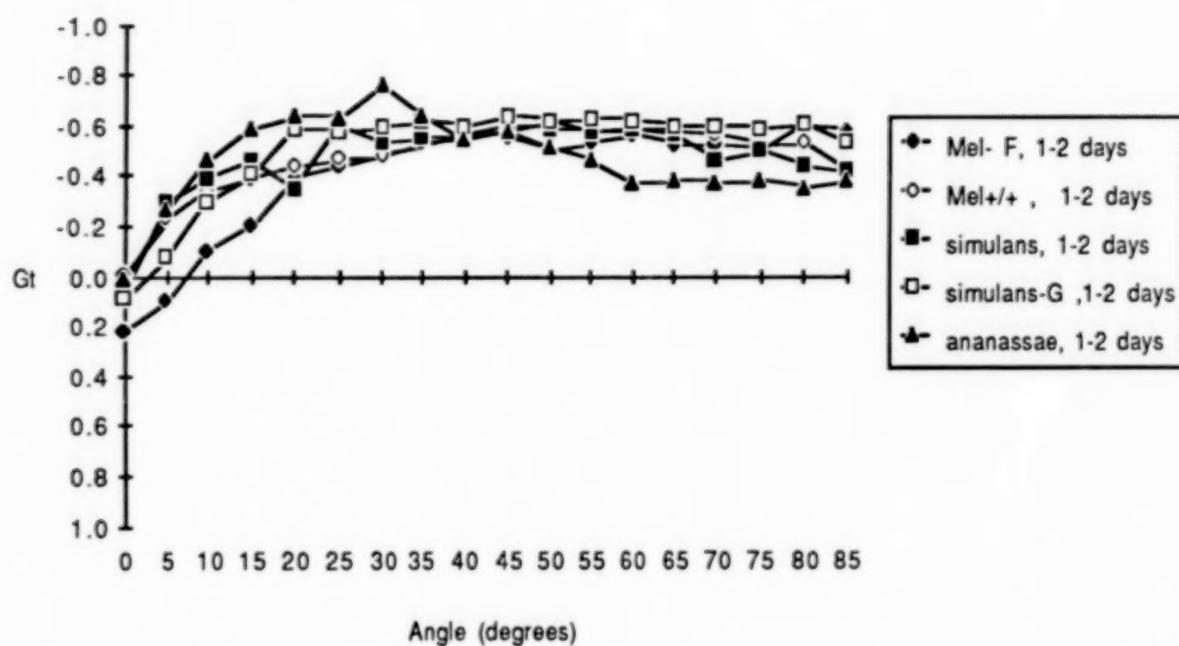
Fig. 2b. Geotactic profiles of closely related strains and species in the D. melanogaster species group (Age: 7-9 days).

Angle (degrees)
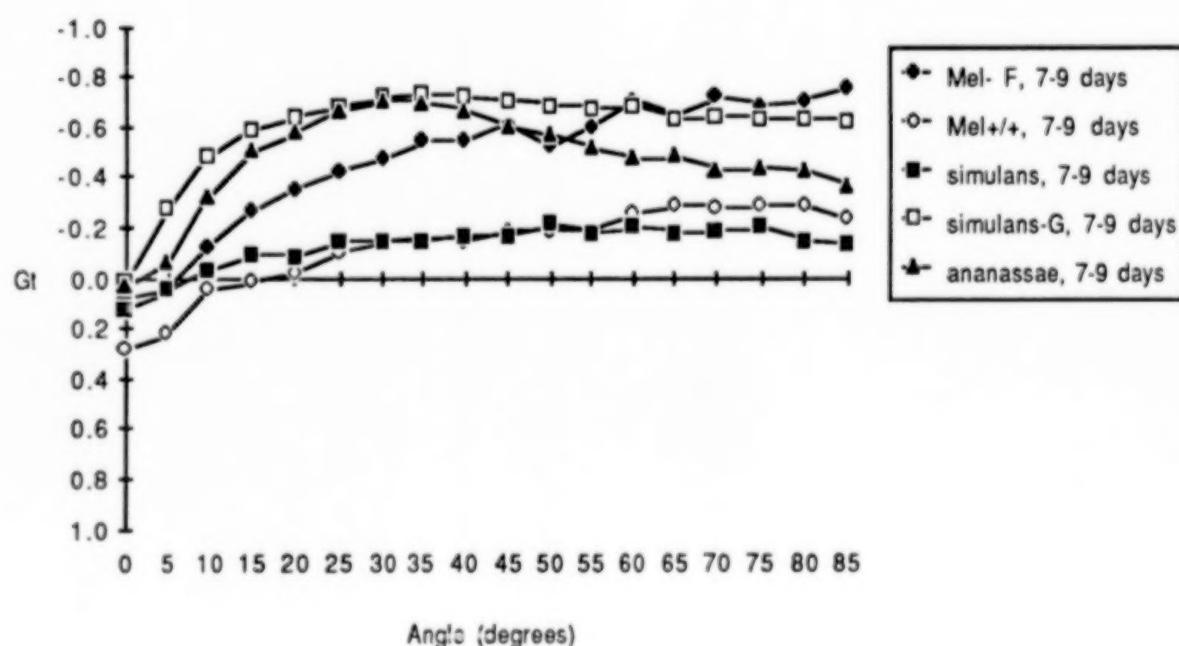
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PROJECT EXPLORER TAKES ITS SECOND STEP: GAS-608 IN ENGINEERING DEVELOPMENT

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Abstract

As a continuation of its Project Explorer series, the Alabama Space and Rocket Center is sponsoring the development of two additional Get Away Special payloads. This paper gives details of GAS-608, including descriptions of its six experiments in organic crystal growth, roach eggs, yeast, radish seeds, bacterial morphology, and silicon crystals. It also presents a brief summary of GAS-105 and the Space Camp program for stimulating student first-hand participation in space flight studies.

Continuing its series of Project Explorer payloads, the Alabama Space and Rocket Center (ASRC) is sponsoring its second Space Shuttle Get Away Special, GAS-608. Currently in its development phase, GAS-608 will carry six student experiments in a standard 200-pound, 5-cubic-foot cannister. In addition to these experiments, which will involve biology, crystal growth, and biochemistry, the cannister will also carry a centralized package for electronics and power supply. The purpose of this paper is to briefly review Project Explorer and its activities and to present some details of the components of GAS-608, along with a quick look at GAS-105.

Background

Conceived to stimulate interest in space flight in the educational community, Project Explorer is a program created by ASRC in cooperation with the National Aeronautics and Space Administration (NASA) and local universities. It is conducted with technical assistance from the Alabama/Mississippi Section of the American Institute of Aeronautics and Astronautics, Marshall Amateur Radio Club (MARC), and numerous volunteer-consultants. Explorer supports the Center's vigorous and expanding set of activities for youth and adults in the famous Space Camp. It does so by providing technical personnel to explain space flight principles and current NASA programs.

Less well known are Explorer's arrangements to promote wider participation in space flight by offering actual flight opportunities. Students attending Space Camp whose experimental proposals are accepted are then invited to develop them in full with aid from Explorer personnel. The initial payload in the Explorer series, GAS-007, was successfully flown on the Space Shuttle Columbia as mission STS-61C in January 1986. Papers in earlier proceedings volumes of the GAS users' symposium furnish the reader with more depth on the design and development of GAS-007 (1-4, 6, 8). Details of the post-flight review of its results are given by Rupp (7) and also in another paper submitted for the proceedings of this conference (9).

Motivated by the success and appeal of GAS-007, ASRC has reserved the use of two additional payloads to develop new sets of student experiments. The first of these, GAS-105, is in development cooperatively with the Consortium for Materials Development in Space under the direction of Francis Wessling at the University of Alabama in Huntsville (UAH). Details on it have been provided by Wessling (5). GAS-608, the subject of this paper, is being developed separately in cooperation with UAH.

GAS-608 Experiment 1

Experiment #1, being prepared by Bryan Agran of Rye Brook, New York, will investigate the effect of low gravity on the incubation of fertilized eggs of the cockroach, Periplaneta americana. Some 10-20 capsules of 30 eggs each will be held in place with soft plastic packing inside a sealed, thermally insulated chamber. The eggs will be selected so that they represent different growth-cycle stages. An eight-week supply of food and water for the roaches will be carried as a "contingency hatching" measure. Humidity control is to be provided with a "dimplewick" water container. Agran's design calls for an ambient temperature range of about 10 $^{\circ}$C to 30 $^{\circ}$C for the dry nitrogen gaseous environment at one atmosphere pressure. After the mission has ended the sample roaches will be returned to Earth for hatching. Their behavior will be compared with a ground-based control sample to seek differences in balance, orientation, equilibrium, and habits such as feeding and reproduction.

Radish Experiment

As Principal Investigator for Experiment #2, Jay Andrews of Manlius, New York, is developing a study of the germination and growth of Raphanus sativus (radish) in an anaerobic environment under microgravity conditions. Sample seeds will be retained on a tray inside a chamber with dry nitrogen gas thermally controlled to a range of 20 $^{\circ}$C to 30 $^{\circ}$C. A directionally uniform low-intensity lamp will provide illumination for growth. Infrared photographs and atmospheric samples will be taken at timed intervals to support the study. Upon receipt of a start signal Andrews' apparatus will pressure-feed nutrients to the seeds in the form of Knop's solution and White's solution, along with dilute methylene blue. At a scheduled time the plants will be exposed to Formalin to terminate their growth. The preserved specimens will be subjected to post-flight morphological analysis and microscopic examination of tissue orientation and organization.

Yeast Genetics

The third experiment on GAS-608, static in nature, is being directed by Greg De Lory of San Francisco, California. De Lory's objective is to determine the effects of certain high-energy space radiations on the genetic mutations of a yeast, Sacchoromyces cerevisiae, and its variants. Some 30 lyopholized, or freeze-dried, samples of this yeast will be tested. Among these will be the haploid (single-strand) strains LBL1, LBL1/n, and KK1-122; a diploid (double-strand) strain that is

a hybrid of LBL1/n and KK1-122; and possibly tetraploid (quadruple-strand) strains. The samples are to be kept in small tubes secured in an aluminum performated plate which serves as a support structure. After reaching orbit the specimens will be exposed to X rays, gamma rays, and cosmic rays (ionizing charged, heavy atomic nuclei). Thermoluminescent detectors may be used as a passive particle counting system. Upon return to Earth the yeasts are to be examined for the radiations' effects on mitotic and meiotic chromosomal changes. The responses of the flight yeasts to selected chemically treated test plates will help determine any genetic changes, and these results will be compared to the patterns shown by Earth-based control samples.

Bacteria Morphology

Experiment #4, with Tom Malone of Roswell, Georgia, as Principal Investigator, will seek to find the influence of low gravity on colonial morphology of a specie of phototrophic bacteria in an anaerobic environment. A secondary objective is to evaluate the effects of bactericidal and bacteriostatic agents on growth of the colonies. Malone's approach is essentially visual: his bacteria will be exposed to a light source for a fixed time, photographs made periodically, and the growth process terminated upon signal. A post-flight analysis using photomicroscopy will compare morphology for the colonies flown in space to that for Earth-based control samples. The hardware plan calls for a sealed chamber which houses a 35 mm camera with a large film capacity; a thermometer; small fluorescent lamps as light sources; resistance heaters for thermal control; and sample plates treated with a sulfur agar growth medium. In addition to these major components there will also be a TattleTale II microprocessor with 224 K bytes of random access memory for sequencing, timing, thermostatic functions, and storage of data. Upon receipt of a start signal and electrical power from the central electronics assembly, the microprocessor, using a custom-written program, will exercise complete control over the experiment.

Silicon Growth

The fifth experiment has been dubbed SIGMA for short--Silicon Ingot Growth for Microgravity Application--by its Principal Investigator, Seth Watkins of Rye Brook, New York. In his arrangement several silicon samples will be heated in a furnace for approximately 50 minutes each. Crystal growth will be initiated for the samples in a dry nitrogen atmosphere. With electrical power provided from the central electronics assembly, Watkins' experiment is intended to run automatically once the start signal has been received. The objective of his study is to evaluate the influence on crystal quality, including dopant distribution, of the space environment. A comprehensive determination of the properties of the space-grown product will be made upon return of the samples to Earth.

Organometallic Crystals

Growth of linear conducting organometallic crystals by an electrochemical process is the general objective of Experiment #6. Developed by Ray Cronise IV of Huntsville, Alabama, his plan is to try to use the microgravity environment to eliminate the lattice defects which customarily reduce electrical conductivity in Earth-grown crystals. In this experiment Cronise will have three small samples of potassium tetracyanoplatinate (TCP) organometallic "complexes," and possibly their halogen derivatives, in aqueous solution. Application of a small voltage across each of the electrolytic cells is expected to form the desired products. Thermal control is particularly important to the growth process, and special design features are being incorporated throughout the apparatus to minimize heat losses. Additional details of Experiment #6 are given in Cronise's paper for this symposium (10).

MARCE

As was the case for GAS-007, the lifeblood of the GAS-608 cannister will be a system prepared for Explorer by MARC. This portion of the payload, designated as MARC Experiment (MARCE), will have a physical configuration similar to that used for GAS-007. Among its major components for this new payload are a microprocessor with memory for data storage and a solid rocket booster battery having a capacity of 50 amp-hr at 28 vdc. The battery will supply electrical power to heaters and other equipment in the cannister. The radio subsystem previously incorporated in MARCE for GAS-007 will be removed. Modifications to the microprocessor software will be made to fit the requirements of the six experiments. MARCE will again provide signals for power-on and power-off, sequencing, and timing. Such measurements as voltages and cannister temperature and pressure will be stored in its memory for post-flight analysis.

Development Status

When development of the individual GAS-608 experiments has been completed, the integrated package will be subjected to systematic testing prior to shipment to the Kennedy Space Center. While a precise mission assignment has not yet been made, it is expected that GAS-608 will be Shuttle-launched into a low Earth orbit with an inclination of 28°. A minimum mission duration of five days is being sought for full experimental results.

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A RELIABLE DATA COLLECTION/CONTROL SYSTEM

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ABSTRACT:

The Cal Poly Space Project requires a data collection/control system which must be able to reliably record temperature, pressure and vibration data. It must also schedule the 16 electroplating and 2 immiscible alloy experiments so as to optimize use of the batteries, maintain a safe package temperature profile, and run the experiment during conditions of microgravity (and minimum vibration). This system must operate unattended in the harsh environment of space and consume very little power due to limited battery supply. This paper addresses the design of a system which meets these requirements.

A RELIABLE DATA COLLECTION/CONTROL SYSTEM

The cylindrical 2.5 cubic foot getaway special cannister donated by Robert Mager and associates is being utilized to perform 2 immiscible alloy experiments and 16 electroplating experiments in the microgravity of a low earth orbit afforded by the space shuttle. A computer system is required which will reliably control the sequencing of experiment events and accurately collect data from the temperature, pressure, vibration, voltage and current sensors which monitor the physical state of each experiment. The experiments must be scheduled in such a manner so as to optimize use of the batteries, keep the temperature of the cannister within a safe range, and conduct the experiments during periods of minimum vibration. The design issues discussed in this paper are: the techniques for improving reliability, the electronic hardware choices, and an overview of the software functions.

A variety of methods for increasing the reliability of the data collection/control system were considered. This design implemented three classes of reliability techniques: 1) fault avoidance, 2) fault detection, and 3) dynamic redundancy (reconfigurable duplication). Examples of fault avoidance techniques are: a) component burn-in (to get past infant mortality rate), b) use of high quality mil-spec screened components, c) good circuit assembly techniques (thorough inspection and testing of the assembly), and d) protective packaging (conformal coating, rf shielding, etc). Two types of fault detection are employed. One is a watchdog timer which is preloaded prior to the execution of a functional block of code with the maximum acceptable time for execution of that function. If the timer times out then a (triple redundant) memory location is checked to find out what function was in progress and the appropriate re-execution occurs. The other method of fault detection is the liberal use of checksums on critical memory transfer operations. These techniques provide recovery from transient faults. A catastrophic fault (component failure) is detected when the number of attempted re-executions of a functional block of code reaches a pre-defined limit. This is when the third reliability technique (dynamic redundancy) comes into play. Rather than gracefully degrade to a more limited functional state, a complete backup microcomputer system is instructed to resume the task of the primary module. During the normal course of operation the backup module periodically exchanges a status byte with the primary module. This status byte indicates what process has been successfully completed, or if an error condition occurs. The backup system is reconfigured to take over the control and data collection function if the

proper error status bytes are received or if no status bytes are received during the intermodule communication. If a further catastrophic failure occurs, the backup system will attempt to continue functioning in a gracefully degraded fashion by switching off power to the bad component. Several voltage regulators are employed which allow power to be turned on/off to the various subsystems such as A/D converters, D/A converters, and the serial communications link. In the case of battery power failure the memory and real time clock have a backup battery which provides approximately four months time and data retention. This also protects the data from inadvertent loss due to battery disconnect.

The next stage in the design after researching ideas for reliability enhancements was to decide on the hardware which would be used. The requirements of low power, operation in an electrically noisy environment, and wide package temperature profile dictate the use of mil-spec CMOS components. Several candidates (CDP1802, NSC800, 80C48, 68C02) for microprocessors were considered and the NSC800 was chosen. The CMOS NSC800 is available in full 883B military specification (temperature range: -55 C to +125 C). It utilizes the powerful Z80 instruction set and features a multiplexed address/data bus and five interrupt request lines like the Intel 8085. The similarity to the 8085 is beneficial since my previous design experience is with the 8085. The microprocessor and some of the related peripheral chips are readily available free of charge through the generosity of National Semiconductor's parts grant program to the EE/EL department at Cal Poly. National offers a full line of CMOS components and dedicated peripherals which allow implementation of the required features while keeping the interface circuitry simple. One such peripheral chip is the NSC810 - 128 bytes ram, 22 I/O lines and two programmable 16 bit counter/timers. The NSC810 provides the function of watchdog timer, scratchpad ram, and 22 lines for monitoring and control. Another peripheral chip, the NSC858 UART (universal asynchronous receiver/transmitter) provides serial data communications (RS232 port). This serial port is used to link the primary microcomputer system to the backup for transfer of status bytes as well as facilitating transfer of experimental data from ram to another computer upon completion of the mission. Analog-to-digital conversion is performed by two National ADC0816's. Each ADC0816 features a 16 channel multiplexer and 8 bit analog-to-digital converter. This means up to 32 sensors can be monitored. Continuosly variable control of the two immiscible alloy ovens is achieved using a DAC0830 digital-to-analog converter linked to a dual 4 channel analog multiplexer (74HC4352). The timekeeping function and processor wakeup is provided by the MM58167 real-time clock (RTC). This RTC also features a low power standby mode. Battery back-up and chip select logic for the ram is provided by the Dallas Semiconductor DS1221. The data storage medium is two 32k x 8 static rams manufactured by Fujitsu (84256), though any 32k x 8 cmos ram is satisfactory. The program is stored in a 16K x 8 EPROM (27C128). The data bus is buffered using National's 82PC08 bidirectional transceiver. The low order address bus is latched (data and low order address are temporally multiplexed) and

buffered using the 74HC373 octal D-type latch. The high order
address bus is buffered using the 74HC373 with latch enable tied
inactive. Intersil's ICL7663 micropower voltage regulators are
used because they have a logic input which allows them to be
turned on and off. Separate regulators (with a flip-flops to
latch the power control signals) are used for the D/A section,
the A/D section, the communications hardware, and one for the
microprocessor circuitry. This helps implement the graceful
degradation reliability technique (if a section fails it can be
shut off leaving some degree of function). The processor's
regulator is turned on by the real time clock interrupt signal
which is generated once every 60 seconds. It is then up to the
processor through the NSC810 to turn on the power to other
subsystems as they are needed; or if appropriate, to turn its own
power back off. This feature keeps idle time power consumption
to a minimum. The ICL7663 also provides programmable current
limit protection. The flip flops and memory mapped I/O chip
select and other "glue" logic is implemented using high speed
cmos parts (74HC112, 74HC138, 74HC00, 74HC04, etc). Aside from
bypass capacitors, resistors, and transistors the electronic
hardware has been described as it relates to the system function.

The next part of the design description is an overview of
the operational scenario. This forms the basis for a software
specification which gets translated into a flow diagram and then
eventually gets programmed into assembly language and henceforth
loaded into ROM. This is the portion of the design which is
currently being developed. The processor normally is turned on
once per minute by the interrupt from the real time clock. When
it turns on it first checks a status byte which tells if it is in
orbit. If this status byte is not present it checks for a
signal called ACTIVATE (initiated by the shuttle astronauts
indicating orbit has been achieved). When the ACTIVATE signal is
detected, a byte is set which tells the processor on subsequent
wakeups that the package is in orbit. In response, another signal
called ACKNOWLEDGED, is sent to an indicator in the shuttle
saying that the ACTIVATE signal has been received. A third
signal line called CUTPOWER is connected directly to a relay in
line with the battery supplying power to the experiments. This
provides a master shut off in case something goes awry and the
astronauts wish to kill the experiment. When in orbit the
temperature and vibration of the package are evaluated and if
conditions are satisfactory then it is time to perform the
experiments. The tentative schedule is to run one immiscible
alloy, then eight electroplating, the other immiscible alloy, and
then the other eight electroplating experiments. During
immiscible alloy experiments the power is not turned on and off
for power savings but rather the power-save feature of the NSC800
is utilized between readings. The temperature resolution of the
ovens is approximately 4 C (the upper oven temp is 1000 C).
Temperature is recorded once per second and the temperature of
the ovens is increased by 4 degrees twice per minute. A timer in
the NSC810 and the real-time clock provide the time base for
sampling and oven control. The electroplating experiments do not
require close monitoring and so the processor power is turned
on by RTC interrupt and turned off after taking a voltage and

current reading once the individual electroplating cell is
powered up. After the programmed time period the cell is then
turned off and the next electroplating cell in the series is
activated. When the experiments are completed the time and date
are the last thing recorded in memory and all status bytes are
returned to the inactive state and the ACKNOWLEDGED signal is
turned off (which lets the astronauts no the experiment has
powered down). Upon return of the Get-Away Special package from
NASA the data is transferred from the non-volatile ram into
another computer for processing and analysis.

In conclusion, the data/collection and control system has
been designed to complete a task reliably and accurately and even
in the event of limited component malfunction. I have learned a
great deal throughout the design and implementation of this
project. This effort has given me experience which helped land a
job doing software development for microprocessor-based
instruments. This project was not without setbacks, the
explosion of the shuttle Challenger caused a serious morale
problem which has delayed completion as well as drastically
reduced the number of members in the Cal Poly Space Project.
We've got the ball rolling again and plan on being finish with
the whole package in March 1988. My interest in the space
program is still alive and healthy and I hope to add my name to
those who've helped in the conquest of the endless frontier.

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GAS #450

A Space Payload for the People
Central Coast Student Experimenters

Glen Ray, Payload Manager
American Institute of Aeronautics and Astronautics
10 August 1987

GAS #450

A Space Payload for the People.

Abstract: The purpose of this paper is to describe the GAS Payload #450. This dicussion includes the peoples' efforts, the experiments, lessons learned, and a few powerful positive steps toward community involvement. The following is a list of experiment titles: "Guppies in Space," "Electrophoresis of Enzymes in Microgravity," "Diffusion of Ions in Solution," "Space Cement," "Bubbles in Space," "Small Particle Studies," and "Liquid Separation in Microgravity."

History: To better understand the background of this payload, the following information and philosophy are presented. The American Institute of Aeronautics and Astronautics (AIAA) founded the GAS project to encourage community involvement directly with the civilian space program, and to strengthen local relations between people and significant civil aerospace entity at the Vandenberg Western Space Center. A request for proposals was issued to the Central Pacific Schools District, including intermediate, high schools and colleges, as the payload social purpose is to provide the people of the Central Coast an avenue through which they could become involved with the space program. The above request thereby challenged the youth within the educational system to "get active in life, in space." The path is positive, fulfilling and fun! We finished the first draft of the PAR just prior to the Challenger incident. All experimenters achieved significant progress as demonstrated through maturing breadboard experimental hardware. Several experimental groups have already developed flight hardware prototypes. Post-Challenger, the first PAR telecon was actualized. The Safety Data Package has been outlined and is in work. The prototype payload chassis has been fabricated in order to define detail integration ideas and concerns. These latest efforts are specially significant in the current political atmosphere of weakly defined space program direction as influenced by the current administration. There is positive progress in work going on out here in the real world! The progress is directed towards healthy fulfillment in life goals by a direct practice into the art of engineering as defined by: the process of manifesting an idea or dream into three-dimensional first person realities. The history aspects would not be complete without mention of NASA GSFC's Special Payloads Division and endless support, enthusiasm and patience. Their dedication to the advancement of science and self is role-modeled by these people in their support of our diminutive and austere projects.

People Considerations: As the GAS 450 project is as much an effort of human exploration and fulfillment as it is one of data return, the people factor is discussed as follows: At the heart of the project are the student experimenters. These people are full of the stuff of youth and eager for directions in which to channel their energies. Our society at large does not provide adequate role models or opportunities for young folks to challenge or apply themselves to. The media–TV, radio, and periodicals, etc., see these young believers as consumers to exploit, rather than the ambassadors and creators of our collective future, in these times of conservative protectionism and space budgets on directive of the administration. It's difficult for anyone to channel energy into such an idealistic and abstract direction as space exploration. The h... innate desires to reach outwards into the nebulocities of near and far space are stymied by the global noise of increased profits, greed, and power. The resultant imbalance of wealth, hunger, and sickness require an inordinant amount of human energy and effort to counter. The humanistic efforts are ongoing, if only the insensitive and abusive causal factors' price of the waste rather than the precious overtaxed resources of the human conscious. It's not to dwell on the obvious planetary disuse and inhumanitarianism dealt by the powerful few, rather, to the cause of encouring and rallying the positive energies of those who desire pursuit of the subtle paths, civil space sciences and research. The GAS opportunity, in our case, has provided upwards and hundreds of people of all sorts, an avenue to apply their creative energy into their own tenuous wisp of space research, supposedly available only to the degreed and opportune. The path is good, as evidenced by psychic enrichment and fulfillment of those who've participated in the effort. Smiles everywhere, as supplies of abundant energy, timeliness accomplished despite all sorts of different obstacles and pitfalls. Always the positive, upbeat attitude; the

"can do" outlook!

Even now, a year and a half since Challenger, the GAS symposium is ongoing. A rally point to us, the advisors, and to our young charges. The students and advisors look to us for guidance of outlook, we look to Goddard and NASA. Admittedly, the last eighteen months have been rough as well out here on the Pacific Coast. An electrical integrated test was scheduled for May 1987, to which no response was received. But then again, ego and batteries needed to be charged, as well. The experimenters' purpose in this GAS is for the people. Discovery is scheduled for summer of 1988. New potential is arriving into the middle and high schools, as our veteran seniors now are into the "real" world where survival demands energy and free time is indeed a luxury. So we, the GAS organizers are building fresh presentations for the freshmen, the new and non-initiated, the underclass of young women and men. To again rekindle efforts of meeting after school for fun and learning. To discover what's been built previously, how to fit components into smaller spaces, use less power. To re-emphasize safety concerns, improved means of simply reacting loads, prevention of short circuit potentials; heaps of work left to perform. The human potential is here, in all people. These students of life who elect to work the GAS project, they haven't yet learned to turn themselves off, to say "I can't build spaceships. That's only for science fiction and the military." These youngsters of all ages are doing work at lunch, after school, over the weekend, because they know a chance exists for their handiwork to fly in space, to create an original datapoint for personkind and science, and most importantly of all, to make an idea real, to be in life rather than watch it go by!

The current focus is to regain the creative momentum of the experiments and support people's paths after the summer vacation. Visits to each of the schools are necessary to expose the new and returning to the projects. Information on GAS 450 status as well as the ongoing shuttle recovery are necessary to provide an overall picture. This is required so personal decisions can be made regarding levels of commitment. The most encouraging news we have was that delivered at the 1986 symposium by Dr. Noel Hinners. His statements with regard to ongoing shuttle flights of GAS cans as secondary payloads despite lack of mention on the official manifest, is most encouraging. Mention of space station cans with experimenter visits on orbit are the most tremendous hope generator we have today. The kids', the adults' eyes and imaginations ignite with creativity upon learning of this incredible opportunity. All this energy needs focusing into our current efforts to get the first Central Coast student payload into orbit.

GAS 450 Project Organization: Each of the experiments has a faculty advisor who coaches and counsels the student experimenters. The advisors provide their individual experience and expertise. These contributions fine-tune the student's learning experiences, through solving problems, i.e., battery power usage and distribution, experiment control and design and fabrication, chassis design and fab and fab and refab, etc. . . We found we could develop and improve the designs endlessly. We only began to finalize our designs as the PAR approval became emminent. The Challenger accident gave us a new opportunity to continue to develop our ideas, and regroup, and find new people to fill the opening made by those graduating and leaving the area.

Schedule Organization: One of the guided objectives is to provide the students with an experience similar to the aerospace industries at large. Meeting organization, action item discipline, and schedule milestones processes are utilized to enhance the aura about the project. The following development schedule (see fig. 1) was overlayed on the standard Goddard template in order to pace our work. This has proven very helpful both in getting milestones accomplished and ideas actualized, thereby providing a rare experience for the practice of skills required of these future pioneers of humane research and life. The pacing schedules and commitment to go ahead with the idea developing are determined through a group concensus process. Plenty of meetings get a lot of work done for this group. Communicating both at their respective labs, or collectively at the marathon work meetings, enhances the learning process. The ideas come fast with these young, unencumbered minds, fueled with creating energy, imagination and fired by the glorious feedback of reinforcement provided by building and creating space hardware.
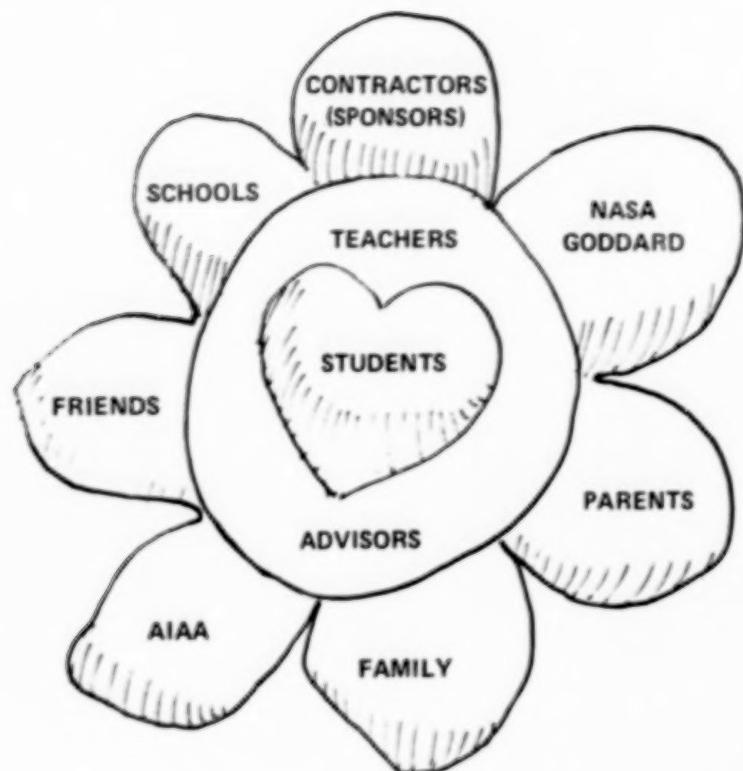
Fig. 1 ORGANIZATION CHART

CONTRACTORS (SPONSORS)

SCHOOLS

TEACHERS

NASA GODDARD

STUDENTS

FRIENDS

PARENTS

ADVISORS

AIAA

FAMILY

60° MODULE

INTERFACE PLATE

"HATBOX"

120° GUPPY MODULE

TENSION CABLE

MODULE CARRIER CHASSIS ASSEMBLY
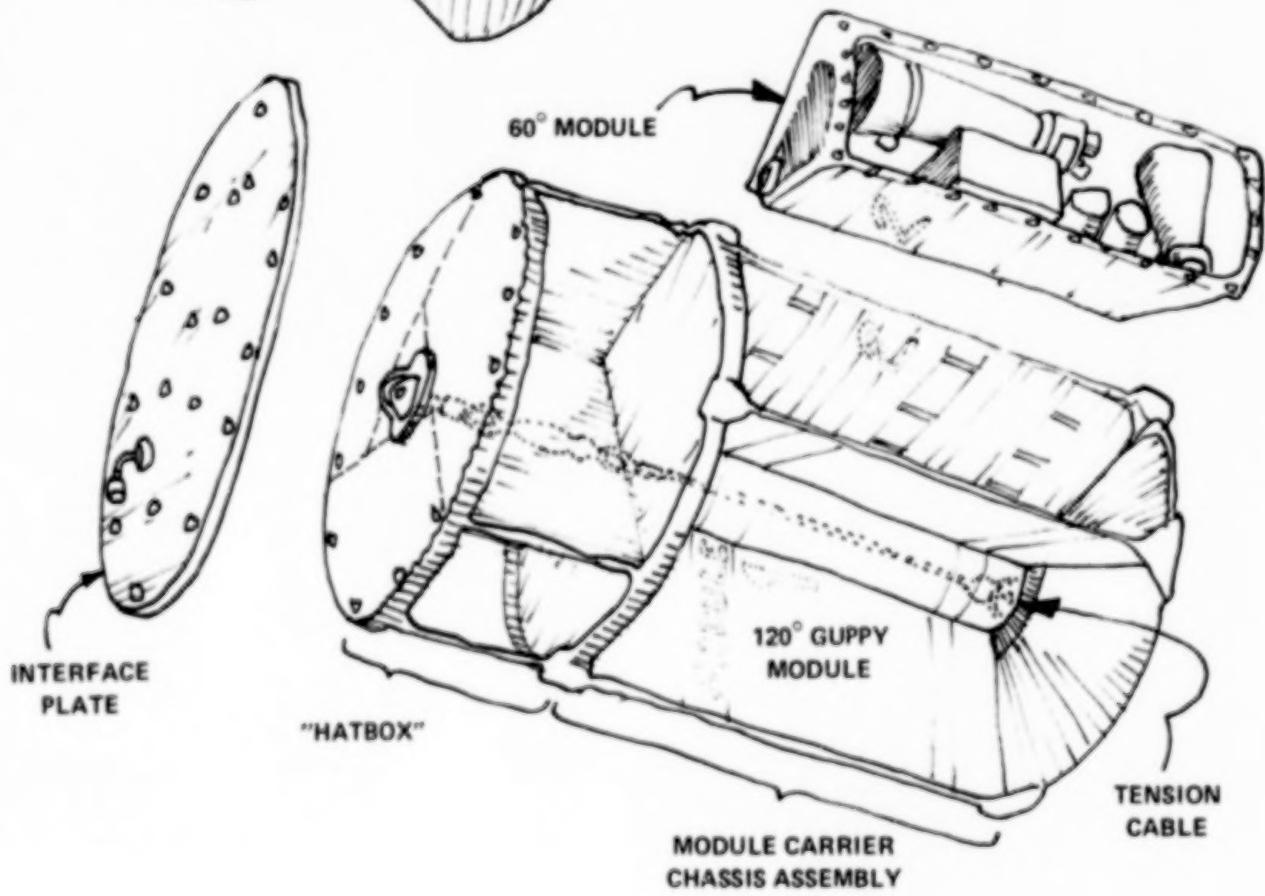
Fig. 2 PAYLOAD CHASSIS LAYOUT

Canister Chassis Design: The AIAA group sponsoring this canister intends to continue flying payloads after GAS 450. The chassis design was fashioned in a modular manner to accommodate experimental requirements and keep technical and fabrication hurdles to a minimum for follow-on flights. A fabrication prototype of the current design has been built. We have six experimenter groups with developmental hardware in work. Getting six experimenters and their support system into the limited confines of a canister is interesting at best. The volume had to be divided evenly. Ready access to the experiment apparatus was a primary parameter. A segmented approach was chosen rather than vertical stacking to keep chassis assembly to a minimum should the need arise to remove and replace components or replenish material, especially towards the canister center. The fabrication prototype was built to provide a module target volume to work towards, and to provide a start point for the chassis which will carry the experiment modules.

Atop the module carrier assembly is the "hatbox" area, a utility area used for battery storage, controller, heater and miscellaneous volume demands. Demands which start out being miscellaneous, get real "too fast." For example, the power to heat the guppy experiment is provided by batteries. These batteries will fill the bulk of the hatbox volume. The power required to heat an experiment for seven days on orbit added to the surprise. To accommodate the experimental requirements of running circulation pumps for 60 days prior to launch plus 7 days on orbit; cement mixers; provide electrolysis current, elelectropheresis current, and provide power to keep guppies warm. The first battery size estimate using energy densities available to our budget, indicated we need a battery the size of Volkswagen bug! We've since modified the plan, and will continue to minimize power consumption. The guppies' circulation pumps now run only to circulate oxygen and nutrients as required. The bulk of the experiments will be performed before a canister cold sinks below the experimenters' operational temperature, saving heaps of heater power for on-orbit use. So what if the experimenters chill out as long as the experimental reaction occurred while still warm and the data safely stored! We'll continue to improve and optimize until the PAR and Safety Data Package are signed and we're closed out for flight operations.

The Experiments: Payload G-450 is a multidisciplinary package composed of five self-contained experimental modules. Six experiments have been developed by California Central Coast School students. The scientific objectives are as follows:

Module 1 – "Guppies in Space," Arroyo Grande High School. The experimental objective is to demonstrate a closed loop biological system. Judicious use of insulation in concert with heaters and pumps will sustain several Lebisticus Reticulatis species during their passage into LEO. This module will perform intermittent self-operation once sealed into the canister. Water flora will oxygenate the system for the specimens. Heaters will be cycled on orbit to maintain survivable temperatures. General hypothesis research regarding microgravity adaptation to include: 1. Lebisticus orientation mechanism with light source as a reference; 2. Lebisticus reaction to launch in a fluid environment; 3. Effects upon gestation and birth; 4. Reintroduction to gravity in a fluid environment; 5) Closed cycle life support utilizing photosynthesis; 7. Physiological consequences of short-term exposure to microgravity.

Module 2 – "Electrophoresis of enzymes in microgravity", Cuesta College. A commercially developed electrophoresis device, modified for experimenter peculiarities, is being flown to establish microgravity effects on enzyme migration. The package will be thermally conditioned prior to plate activation.

Module 3 –"Space Cement," Dunn School. The objective of this experiment is to mix and cast a batch of cement in microgravity. A liquid will be introduced into a specimen chamber containing dry cement. A mixer will stir the liquid and cement into a homogeneous slurry, and the mixer withdrawn. The cement can now solidify into a near net shape for materials analysis. The grain structure and material properties will be compared with a control sample prepared on planet.

Module 4 – "Bubbles in Space" and "Space Adhesives," San Luis Obispo School/Atascadero School. The objective is to study the process of electrode occlusion during electrolysis in microgravity. Current will pass through the various solutions via electrodes. As the solution is electrolyzed the resultant gas will deposit on the electrodes. The gas will occlude the electrode thereby shutting down the reaction. Data recorded will be amperage, voltage, and time. Space adhesives will compare strengths of adhesives bonded in microgravity with a gravity bound sample. Several adhesives will bond various materials, i.e., brass, steel, copper, aluminum. Adhesive grain structure and bond strength are principal objectives of the study.

Module 5 – "Fluid Separation and Small Particles," Orcutt Schools and AIAA combined module. The objective is to study separation of fluids with varied specific gravities under the influence of microgravity. A timer-activated camera will record separation/mixing of fluids. "Small Particle Studies": this experiment will sample small atomic particles occurring within the shuttle's orbital region. A scintillator type device will be utilized as the primary sample detector. The units consist of a hollow cone with sensitive detectors at the cone apex. As the short-lived, high-energy particles pass through the payload bay and the cones, any cone transit will generate a microflash by the doped inner surface of the cone. Count data from the detectors and clock information will be stored for reduction upon deorbit. The hypothesis utilizes the earth's magnetospheric interaction with the solar wind as a natural high energy particle generator.

Conclusion: If the reader feels interest, energy, and positiveness; and activity has been emphasized through the course of this paper, Good! Another significant purpose is that attitude concept of: "Furthering the humanities cause." Life and appreciation of the planet as a whole, is one of the prime directors.

The Goddard-provided GAS opportunity is a tremendous, enlightening avenue to practice idea actualization and further the scientific human cause. Sincere thanks to the Goddard Special Projects Office. It is opportunities such as these, which entice young scientific minds from traditional "gravity bounded" roles. May these neophyte experiments continue to fly, and pioneer fresh, creative thoughts!

<u>N</u>orfolk Public Schools <u>S</u>cience & <u>T</u>echnology <u>A</u>dvanced <u>R</u>esearch

The NORSTAR Program: Space Shuttle to Space Station

by

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Abstract

Updating the development of G-325, the first high school student-run space flight project: and an overview of a new international program, which involves students from space station countries who will be utilizing GAS technology to cooperatively develop a prototype experiment for controlling a space station research module environment.

Part 1. The NORSTAR Student Research Institute

The NORSTAR project has developed at an incredible rate since last year, and the Get Away Special project has become an ongoing program.   The original NORSTAR Project, which is the first high school student-run space flight project, has evolved into a major science development program in the Norfolk, Virginia Public School system. As a result of presentations made by NORSTAR students to various academic and professional groups, school officials witnessed the high level of skills attained by the students. Springboarding from the success of this GAS experiment project, a proposal was accepted to support the development of a creative, innovative, exciting, and highly visible community oriented program for the advanced sciences. The recommended program was designed to foster excellence in science education in the Norfolk Public School (NPS) system, by developing a student research institute evolving from the NORSTAR Project. It was an excellent time to develop the "NORSTAR Project - Space Shuttle Experiment" into the NORSTAR Student Research Institute. The absolute goal of the NORSTAR Program is to develop the full potential of the student, realizing the highest ideal of education. This program would be similar in some respects to a high technology magnet school within the NPS system, attracting the attention and support of world renowned scientists and researchers, and industries throughout the country.

The need and desire for superlative programs fostering excellence in science education has been established by a host of national educational committees. The original NORSTAR project was the dawn of a new age of excellence in science education utilizing community involvement. The new NORSTAR program represents the full sunshine in the development of one of the finest educational programs that a city could offer to its family of students, parents, teachers,

administrators, and society. The program is, by its nature, open ended and flexible enough to adjust with the rapid changes in technology and society. Through this program, the NORfolk, Virginia public school system has become a STAR in education through innovation, enthusiasum, and interaction with the community.

NORSTAR division curricula incorporate a multidisciplinary, integrated approach which facilitates the most effective learning processes for areas of study including physics, mathematics, computer programming and applications, chemistry, and communications skills through a team approach to solve problems. The teaching environment becomes the actual work environment in which students develop important process/problem solving skills. Perhaps the greatest benefit of the program is the development of life-long process skills, learned in a practical, hands on, exciting experimental environment. Skills include communicating, analyzing, being constructively critical with a proper analytical attitude, receiving and utilizing criticism constructively, responsibility for real time tasks and schedules, and working as member of an integrated team. Students involved with the Student Research Institute are conducting meaningful scientific research for publication, in cooperation with professionals from NASA, the educational community, and industry.

The NORSTAR Student Research Institute currently includes the Space Shuttle Experiments, Robotics, SEER System, and Teacher Research Divisions. Projected programs include the Arts & Sciences Research, and Laser/Fiber Optics Divisions (see Figure 1).

CURRENT DIVISIONS

SPACE SHUTTLE EXPERIMENTS DIVISION

Current work in this division includes the original NORSTAR Project, which is the first high school student-run space flight project ever attempted. The project includes the definition, design, fabrication, testing, analysis, and publishing of the results of an acoustical experiment which will fly on a space shuttle as flight opportunities become available. The experiment has implications for the aviation and space industry in that it tests the process in which an ultrasonic sound field is used to detect flaws or weaknesses in solid structures such as the wing of a jet aircraft (see Figure 2). Future plans for GetAway Special experiments include further ultrasonic/acoustical tests; laser copolymerization studies, and robotics/artificial intelligence applications.

ROBOTICS DIVISION

This program allows students to develop the fundamentals of computer operations and programming, the operation and interface between computers and industrial robotic systems, and the applications and operation of industrial robots. Special projects include the development of space flight experiments in conjunction with the Space Shuttle Experiments Division, and work with mentors from NASA and other agencies on the development of space station robotics technology.

SEER SYSTEM DIVISION

The SEER (Space Station Environmental Expert Research) System Division represents an international, cooperative program including the Space Sciences Academy, Stanford University, NASA Langley Research Center, NASA Ames Research Center, and the Norfolk, Virginia Public Schools. This program currently involves students and teachers from the United States, Norway, and France. Science and educational groups have been approached to develop student teams in Canada, Great Britain, W. Germany, and Japan. Students are developing an artificial intelligence expert system to monitor experiments in remote environments. The development of a telescience operating system is being developed through the guidance of Stanford University. Students will be working with scientists and college students from the various supporting institutions throughout the entire development process of the experiment, including flight and post flight analysis. A flight opportunity for the student developed experiment is being sought after through various
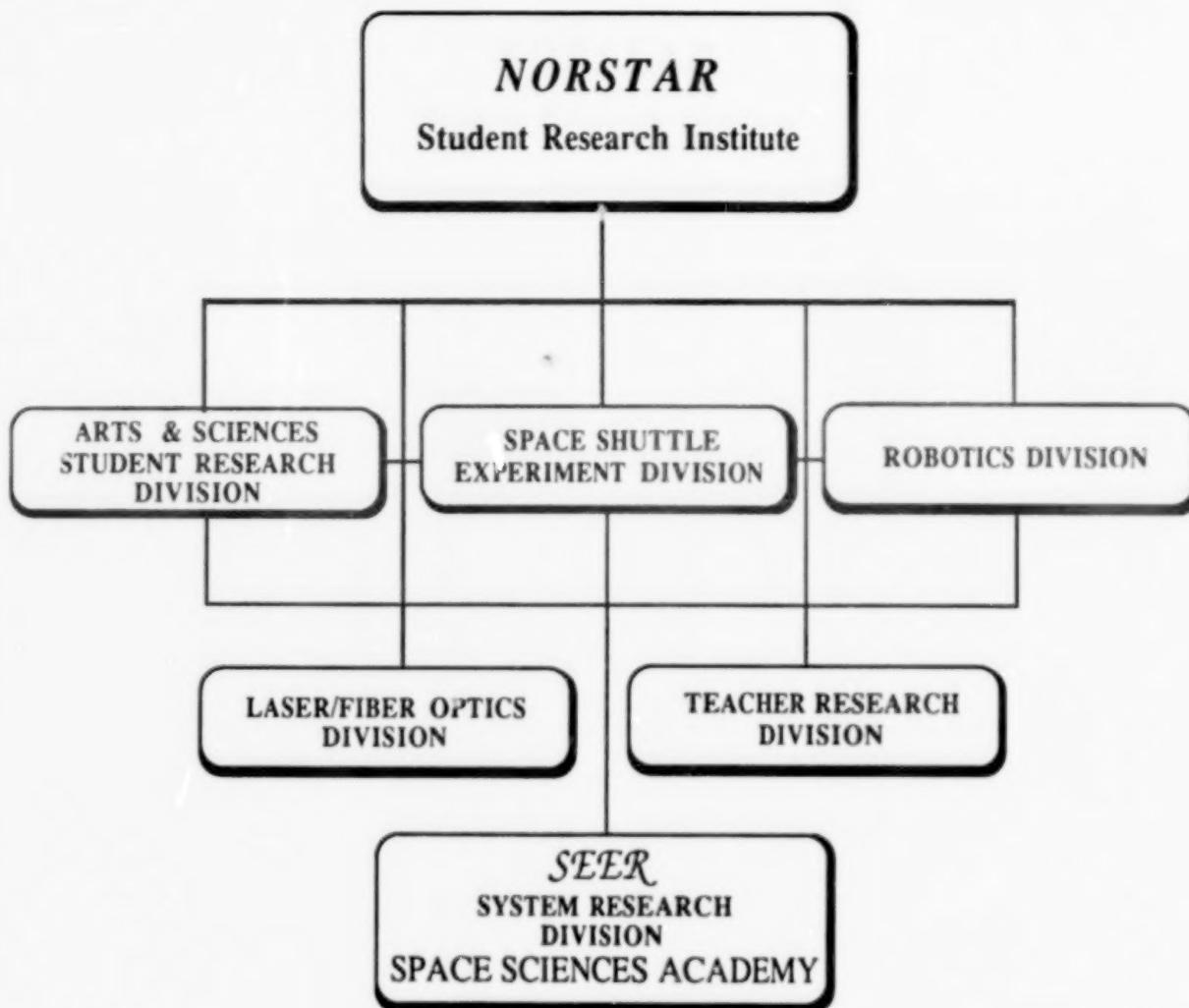
Figure 1. NORSTAR Student Research Institute Divisions

organizations. The SEER project is discussed in more detail later in this article.

TEACHER RESEARCH DIVISION

This division gives teachers an opportunity to conduct their original research in all fields of study, including research for advanced degrees. The teachers have access to all NORSTAR Program facilities, including equipment, databases, and community resources.

PROJECTED DIVISIONS

LASER/FIBER OPTICS DIVISION

Laser and fiber optics technology will be the focus of this division. Students will study the science of state-of-the-art laser and fiber optics technology, while special projects will include the development of a space flight experiment in conjunction with the Space Shuttle Experiments and Robotics Divisions.
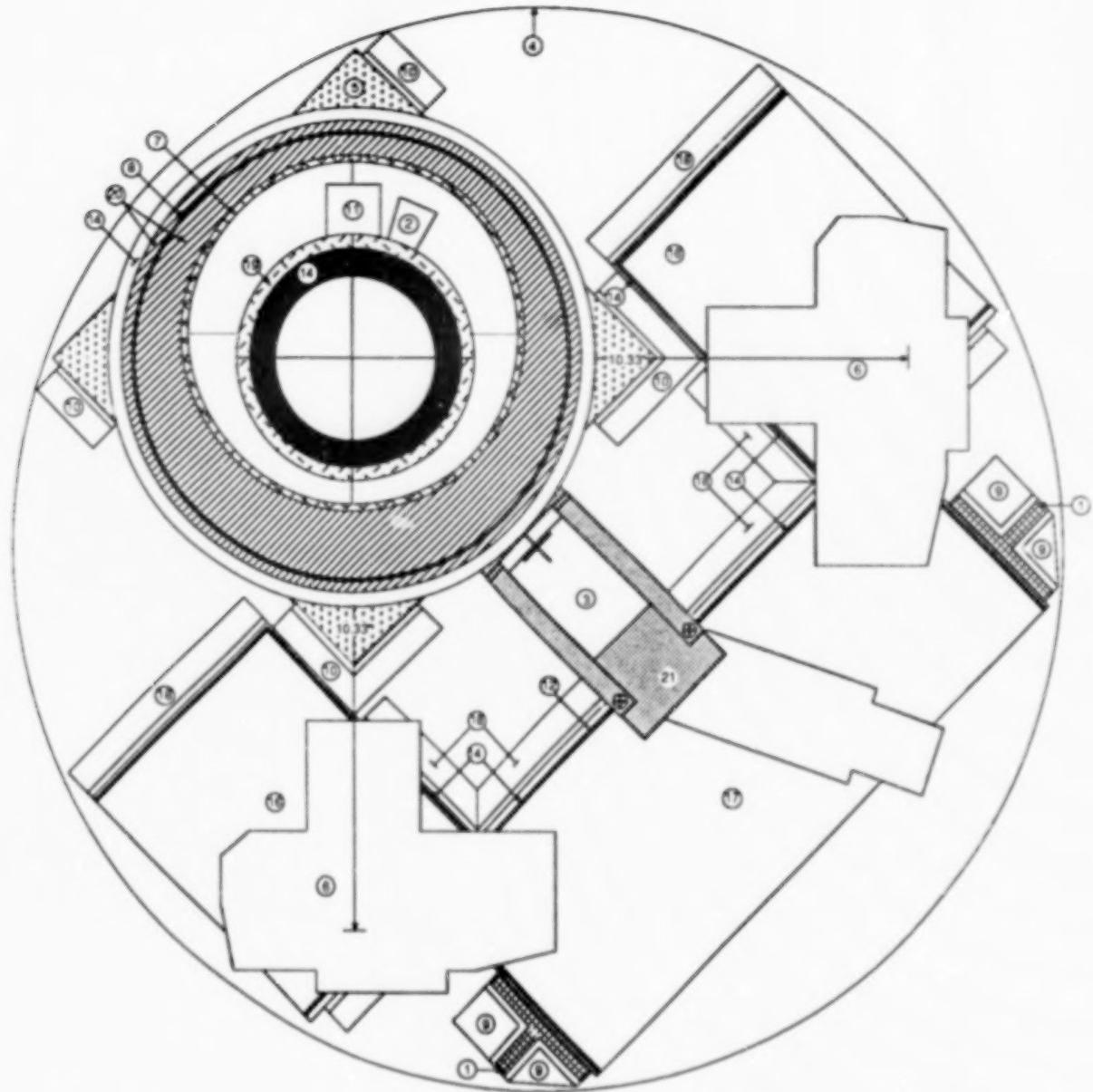
TOP VIEW NOTES

1 T-bars (28.25"L)

2 Expansion device

3 Strobe

4 Outer diameter of mounting plate (19.75"D)

5 Electronics box (8.0"L x 8.0"W x 4.0"H)

6 Camera (see camera mounting drawing)

7 Retaining cylinder (inner radius = 6.25", outer radius = 6.50"; 22.625L)

8 Test Cell wall (inner diameter = 8.125", outer diameter = 8.1875"; 22.875"L)

9 T-bar mounting brackets

10 Electronics box support

11 Sphere containment system

12 Main battery support plate (18.4375"L; 0.125"W; 15.35"H)

13 MSC (inner diameter = 8.625", outer diameter = 9.125"; length = 27.75")

14 Insulation and sound absorbing material (RTV rubber)

15 Test Cell wall (inner diam. = 8.125"; outer diam. = 8.1875"; 22.875"L)

16 4-Pack of batteries (Duracell industrial alkaline ID9260 : 4.565"L;5.5875"W; 15.35"H)

17 8-Pack of batteries (Duracell industrial alkaline ID9260: 12.0375"L;4.5025"W; 14.0125"H)

18 Battery mounting brackets

19 Test cell (Diam.=4.5"; 19"L)

20 Injected foam insulation (A & B foam)

21 Strobe support

Figure 2. Top View of GAS-325 (1:3)

136

ARTS & SCIENCES RESEARCH DIVISION

Original research performed by students with practical applications to community problems is the focus of this division. Experiments providing real local benefits include water sampling and analysis, atmospheric particle sampling and microscopy for the Tidewater waterfront and outfall areas, anti-fouling paint studies, traffic flow study, and survey and marketing studies. Advanced research will also be conducted in research fields related to visual arts, lasers and holography, music, artificial intelligence software development, creative writing, speech/voice synthesis, marine sciences, and materials characterization.

FUTURE DIVISIONS

Future divisions of the NORSTAR Student Research Institute are in the developmental process.

Part 2. The SEER System Project

The SEER (Space Station Environmental Expert Research) System Project is an exciting, innovative student project designed to promote international cooperation. If high school students from around the world could learn to work cooperatively on an experimental project, then we would truly be preparing them for the space station era. The SEER Project was developed at an intensive four week Space Sciences Academy held at Stanford University during the summer session. The multidisciplinary, integrated curriculum of the academy was developed by NASA Teacher In Space finalists, utilizing space science and technology . A full range of disciplines were taught, including astrophysics, computer programming, robotics, creative problem solving, space law, bioflight, journalism, communications, etc.
(see Figure 3). All subject areas were related to space sciences, and integrated into a coherent curriculum for the most efficient transfer of understanding to the student. The program taught by Ron Fortunato (NASA Teacher In Space finalist, Virginia) was to teach the students how to develop a space flight payload, similar to the NORSTAR program in Norfolk, Virginia, where students are working on a GetAway Special payload. An international team of students was formed into a space flight project organization, and professional mentors were sought after for the students, from NASA, space station contractors, and academic institutions, covering the broad range of expertise necessary to develop a payload. A communications network was established under the sponsorship of CompuServe, which allows students and mentors from all over the world to send messages, files, and hold live conferences in the Space Education Forum. This way, any student with access to a computer and modem could participate in the project, even after the Stanford academy was completed. Currently, students from all over the United States, France, and Norway are linked to the computer network. Educators, scientists, and interested professionals are currently being approached to form student teams in Canada, Japan, England, West Germany, and Denmark. A flight opportunity to send the student experiment into space has been requested from the NASA Langley Research Center, in the form of an additional Get Away Special canister, or to have the payload added to an existing NASA payload (LITE - LIDAR In Space Technology Experiment).

SEER project development is twofold, consisting of an artificial intelligence/expert system, and an experiment payload to test the computer system. Students are working on both aspects simultaneously, with student teams responsible for the development of certain components, and ground-based experimentation to build a control database. The basic definition of the SEER system is:

1. To program an Expert System to control the environment of a simulation of a (telescience) experiment flying in the Space Station Laboratory Module. The program should maintain an optimum environment under normal conditions. It should be able to handle emergencies such as puncture by a
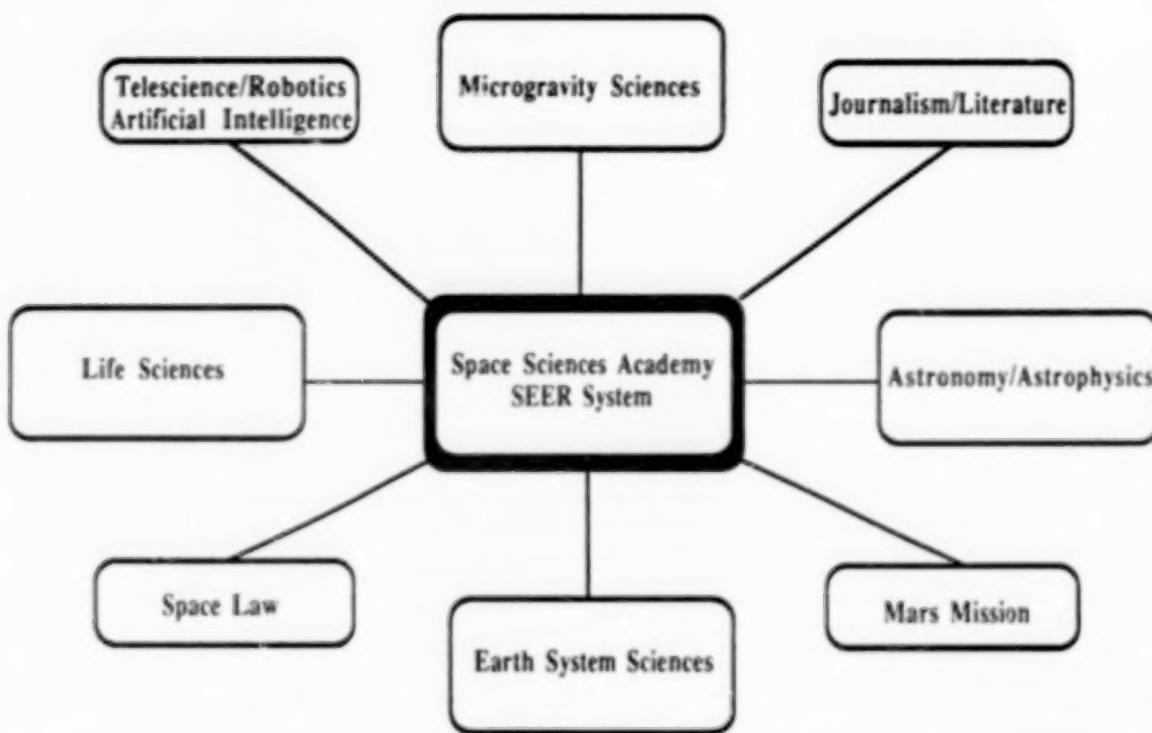
Figure 3. Space Sciences Academy Curriculum Organization

micrometeor, sudden changes in heat flow, and disrupted water flow.
2. To dynamically expand the knowledge base and capabilities of the AI
program, making possible control of the environment of diverse experiments
with a minimum of special programming; non-environmental concerns will
be taken care of by a dedicated controller or by telescience.
3. To design real-world interfaces for the AI system, enabling the
environmental control of actual experiments rather than simulations.
4. To design user-friendly methods of supplying the AI system with
experiment specifications, so that a layman can modify it to interface with a
variety of experiments.
5. To design and construct a set of experiments for flight on a Space Shuttle
experiment pallet, testing the control systems of the AI system in space.

Once these steps are successfully completed, we will have a system capable of "intelligent"
control of the environment in a space flight payload, or perhaps a Space Station Laboratory
Module. This type of system could replace supervision by a mission specialist or technician in

cases where experiments are too hazardous for direct supervision, yet decisions must be made immediately in case of a malfunction.

The experiment that will test the SEER system has been named V-GER by the students. V-GER, an acronym for Variable Gravity Aeroponics Research project, refers to the Voyager probe in the first Star Trek movie. The V-GER experiment will make plant growth observations of an expert system controlled aeroponics experiment in a variable gravity environment. The experiment will monitor the effects of different gravity levels on the following plant growth aspects: growth rate (in height and mass over time), oxygen and carbon dioxide production/use (atmospheric breakdown over time, average respiration per plant unit mass), fluid and nutrient transport (using a dye in the nutrient solution, pattern of stained water in leaf, tissue analysis), cell division rate (root tip densities of dividing cells, other tissues), cellular mutations (tissue analysis), chemical content of plants (plant nutritional values and lignin amount checked through bioassay), morphology, stem/base/mesh growth angles of the root systems, and germination percentage. Since it is probable that more than one kind of plant will be tested, the success rates of different plant species will also be observed. A future experiment may actually deal with testing the plants for vulnerability to diseases (microorganism resistance).

The canister on a larger scale would represent the greenhouse which will meet the agricultural needs of the Space Station. The knowledge gained in the variable gravity aeroponics experiment would be quite relevant in designing a plant growth facility for a Space Station - at the least, the data could be used to confirm the findings of other experiments. Multiple gravity levels would be applied in order to develop data pertaining to different space ventures: zero-gravity for space flight, one-sixth gravity for the moon, one-third gravity for Mars, earth gravity for control, and possibly one-hundredth or one-thousandth gravity for an asteroid mining operation or small moon (see Figure 4).

The critical aspect of the project is the expert system which will control the experiment environment. This computer system will change the environment if necessary to ensure maximum plant growth. Like an aeroponics expert, the system must react to each and every detrimental situation. This program may be modified for use in other microgravity experiments. The Space Sciences Academy students are developing this artificial intelligence expert system to control and maintain the following environmental parameters: atmospheric gas concentrations, temperature, pressure, humidity, lighting, and nutrient spray intervals. Environmental requirements include: atmospheric concentrations - 78.9% nitrogen, 20.8% oxygen, 1000 parts per million carbon dioxide; temperature - 25°C ± 2°; pressure - 1 atmosphere; humidity - 80%-90%; lighting - 1/4 to 1/5 full sunlight.

The SEER Project is sponsored by the Norfolk Public Schools Gifted Program and seeks comments from those in the space and educational community who would be interested in this experiment and wish to collaborate. Any correspondence with the NORSTAR Student Research Institute is welcomed, and may be addressed to:

NORSTAR Student Research Institute
1330 North Military Highway
Norfolk, VA 23502
(804) 466-0701
CompuServe ID# 76703,4306

Motor

Heater rod through axis

Desiccant

35 mm cameras

Battery Pack
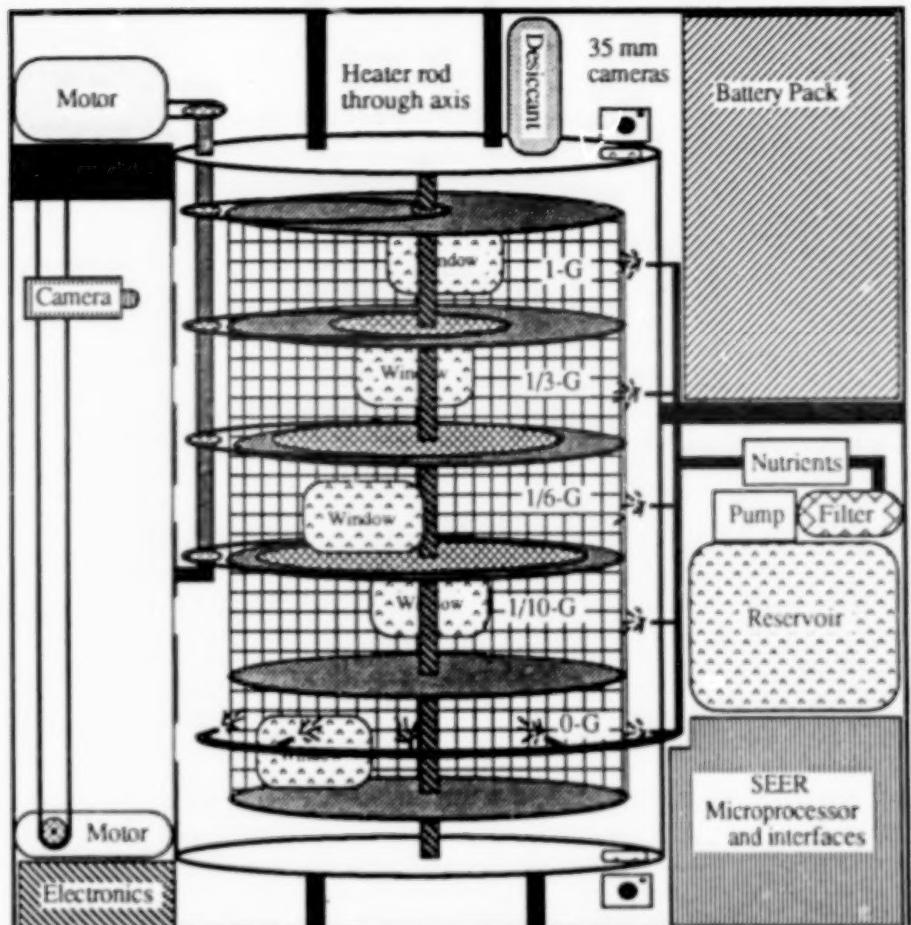
A 61 cm. x 21cm. radius rotating wire mesh drum is the growing medium for the seeds, providing support.

Camera

Window 1-G

Window 1/3-G

The mesh drum is divided into five ringlets. The ringlets are driven by belts of varying lengths to produce different rates of spin and thus different levels of centrifugal force (gravity).

Window 1/6-G

Nutrients

Pump Filter

Window 1/10-G

Reservoir

Water is sprayed from the outside, through the containment tank (CT) onto the roots. Excess water is absorbed by the air.

0-G

Motor

SEER Microprocessor and interfaces

Water is sprayed on the bottom ringlet via a pipe that circles the lower portion of the CT.

Electronics

The video camera moves up and down via a cable on a reversible motor.

On/Off line to Shuttle cabin

= Drum support and axis (may incorporate a heating rod).

= Wire Mesh with cheesecloth layers for holding seeds.

= Gears designed to produce different spin rates.

= Rotating rod from Motor
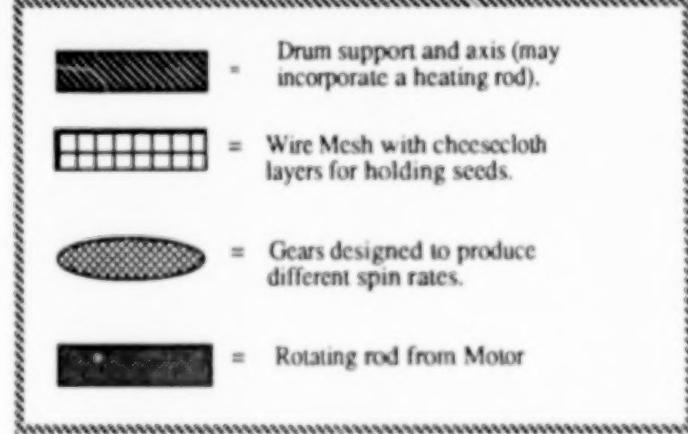
Figure 4. V-GER Experiment Schematic

LIGHTSATS:

and their Attraction to Budget Oriented Federal Agencies

- -

Charles A. Bonsall

Federal Aviation Administration

presented at the

The term "Lightsats" refers to low volume, low mass, low-earth orbit, satellites suitable for launching from Get Away Special (GAS) canisters, or as secondary payloads on expendable launch vehicles. I am aware of only a few recent lightsats including NUSAT I, GLOMR and a number of amateur radio satellites. I know of no civilian federal agency presently operating a lightsat, or with any immediate plans to do so. Yet when Larry Thomas asked for a speaker from the Federal Aviation Administration (FAA) to discuss the GAS program, and particularly its potential for launching lightsats, from the FAA's perspective, I naively agreed to find one. So I started studying the Federal Aviation Administration Plan for Research, Engineering and Development, and talking to people responsible for implementation of this plan. This plan is the official document describing the activities designed to improve the safety, capacity and efficiency of the National Airspace System (NAS) between now and the year 2015, by exploiting existing capabilities and introducing specific new technologies, including satellite-based services. I found very little has been done concerning incorporating specific satellite-based services into the NAS with the exception of the GPS navigation system. And this is to be expected since, until recently, there was little general awareness of the technical and economic potential of lightsats. Consequently, I am not here to present an official view of the FAA concerning utilization of lightsat technology, since that has not been defined yet. However, it has been my experience that the FAA will be very interested in, and supportive of, any new or existing technology that offers potential to improve the safety, capacity and efficiency of the NAS. This morning I intend to tell you what I have learned can be done from the perspective of an individual within a government agency who wants to use a new technology to enhance the mission of that agency. I hope what I learned and will pass on to you will be an inspiration to any government employees in the audience and useful to those of you who are seeking government sponsorship.

For those of you who do not represent government agencies, I believe there are several advantages to gaining the sponsorship of government agencies for your projects. These include:

- Mission Support:

You can usually find an agency whose mission practically requires it to support
your project if properly presented. It is their responsibility and assigned
task.

- Contacts:
In the course of their work many people in an agency get to know the knowledge-
able and influencial people in a particular field. Frequently they have come
out of the particular industry the agency is concerned with and are members of
the associated professional institutions.

- Money:
Although an agency may not have much available money, it is sometimes easier
to justify an expenditure for public benefit, education, research, etc., than
it would be in a profit driven environment.

- Insurance:
Since the government is self insured, if they become the owner/operator of a
satellite the expensive liability insurance premiums can be avoided.

For those among you who do represent government agencies I would like to
point out the benefits received by the FAA from the NUSAT I project.

NUSAT I was designed, built, launched and operated for about twenty months with
a total direct expenditure by the FAA of less than $70,000. Of course, there has
been a great deal more in unidentified FAA employee time, vehicle use, travel, etc.
But I doubt the total was more than $150,000. Not only did NUSAT I provide the
FAA with the experimental data needed to build a future operational system, but it
also demonstrated to the FAA that a small, low earth orbit satellite could be used
for other applications important to its mission. Representatives of the Center for
AeroSpace Technology (CAST) at Weber State College, the organization that evolved
out of the NUSAT I project, are meeting with FAA officials this week to explore
the use of these satellites in Research, Engineering and Development projects for
several FAA programs. The FAA is now open to suggestions for using the low earth
orbit satellite for missions not even considered before.

The public relations and aviation education aspects of this program were
exploited fully. The NUSAT I project is frequently held up within the FAA as an
example of what Aviation Education Facilitators can accomplish. Models and audio-
visuals of NUSAT I, with explanations of its purpose, have been displayed at many
schools in northern Utah, at various NASA and FAA facilities, at the Utah State
Capital, at many fairs and conventions, at the Smithsonian Institution and in the
facilities and magazines of many corporations.

Local FAA personnel have learned how to develop synergistic relationships with
educational institutions. The FAA has completed three other contracts with Weber
State College totalling $4,300 and is presently negotiating at least two more for
about $5,000. Although the amounts of money are small, the benefits to the FAA in
work accomplished which would not otherwise get done and the benefits to students
in practical experience and exposure to real problem solution are out of proportion
to the expenditures.

Perhaps the greatest benefit to the FAA has been an expansion of our vision. We have learned that traditional program management may not be the best way to accomplish every task. We have learned to trust our associates to try creative ways of accomplishing our assigned mission. We have glimpsed the future and our role in it.

Based upon our experience with the NUSAT I and more recent projects, I would suggest that to work successfully with a government agency you will need to keep several common sense principles in mind:

1. Advocates:
In my opinion it is absolutely mandatory that you have an advocate within the sponsoring agency who has the influence and authority to accomplish what you wish to do or can gain the support of such a person. In fact, more than one advocate, at several different levels of the organization is even better.

NUSAT I received support from the FAA not only because a number of local FAA employees dedicated a great deal of time and effort to the project, but because the Regional Director sought and approved FAA support at regional and national levels. In addition, FAA Administrators visited the college and provided top level coordination with NASA officials at key moments in the project.

2. Care and nurture of your advocates:
You must recognize the constraints under which your advocate operates including budget cycles, conflict of interest regulations, personal influence and creativity, professional/technical skills, personal time and dedication, legal/regulatory constraints concerning contracting, etc. Please be understanding and patient, your advocate may be risking his reputation and future effectiveness and promotions on your project.

It is probably futile to say this, but when representatives of your organization make public statements about your project try to make sure they are accurate and not embarrassing to your sponsor. Regulatory agencies take enough heat over true statements. Statements about NUSAT I included such erroneous information as: airports would be shut down for several days without its services, air travel would be much safer when it became fully operational, it is still in use, etc.

3. Relevance to the agency mission:
Your proposed project must directly support the mission of the agency whose support you are seeking. The first reason is simply that agency resources can not be used legally if the project does not support its mission. Secondly, individuals within an agency are likely to be technical experts, and know other technical experts and authorities, in the specialities involved.

The NUSAT I project fitted quite nicely into several niches of the FAA mission. It provided experience in the use of a new technology to solve a technical problem in the NAS. It provided an excellent vehicle for aerospace education which is one of the purposes of the FAA. It enhanced the public awareness of the role of the FAA, which is always important to a regulatory agency. Like all regulatory agencies, the FAA particulary appreciates the rare publicity that is complimentary to it. The FAA enjoyed publicity to the effect that it was applying space age technology to the practical solution of air traffic

control problems at virtually no cost. Although the reports were rarely accurate they were always laudatory.

4. NASA support:
It goes almost without saying that you will need the support and advocacy of the NASA people. Fortunately, it is not very difficult to get their support.

I will not try to list all the people within NASA who made the NUSAT I project a success. Without the complete support of the people here at Goddard, at the Cape, in Houston, at Headquarters, the astronaut corps, etc. NUSAT I would not have flown. I would like to point out that much of their support was above and beyond the call of duty, and not without considerable personal risk.

5. Support of non-government groups:
It is important to enlist the support of related non-government groups such as professional and trade organizations (IEEE/AIAA/SAE/etc.), amateur radio groups, manufacturing or operating corporations, etc. These groups provide influencial support, as well as, personnel, material and financial resources. Just as with the government agency involved, you should seek an advocate within each of these other organizations.

As you all know, the NUSAT I project was almost totally supported by such organizations. Key people in these organizations sometimes made things happen, and at other times, let things happen. In addition, the very fact of their public support created more support within the FAA. A few local engineers proposing a lightsat may well be considered crackpots by their superiors, but when officials of major aerospace companies start to offer support and people see a project will succeed, the agency support is assured. Parenthetically, this type of support also helps an agency in its relationships with elected officials.

6. Demonstrate broad interest and support:
It is important to demonstrate the interest in, and support of, a proposed project by other organizations who may benefit from it.

The NUSAT I project enjoyed the interest and support of Western Airlines, the United States Air Force, the Utah Air National Guard, the British Civil Aviation Authority, the British Defense Ministry and the International Civil Aviation Organization.

7. Educational institutions:
Educational institutions are good places to organize projects in order to find both creative people and cheap labor...   In addition, educational institutions are relatively neutral places where government agencies and competing companies can work together.

Although NUSAT I generally has become associated publicly with Weber State College, it is as much a product of Utah State University. In addition, some very key antenna design, construction and testing was done at New Mexico State University. It is a product of many individuals within these instit- utions and others who were attracted to the project through these institutions. Although many corporations contributed to the NUSAT I project, it would have

been impractical, and in many cases, illegal, for FAA officials to seek these contributions. But we all could work to support a project at an educational institution with no real nor apparent conflict of interest. Partly as a result of this project several new corporate ventures have started which should benefit the local economy, and this is one important function of state funded educational institutions. Another benefit was the successful matching of recruiting companies with the best of the job seeking students.

8. Money:
Do not expect to get vast amounts of public money. Even though an agency may have billion dollar budgets for payrolls, property management, etc. your sponsors may have very little discretionary money for experimental or demonstration projects.

9. Leadership:
You must have the leadership of dynamic, enthusiastic, individuals with the vision, dedication and motivational skills to get a project started and keep it going.

Many of you know the story of NUSAT I. A NASA official advised me to get in touch with Gil Moore. I was a naive young man and made the mistake of spending ten unchaperoned minutes with Gil. Many fellow victims are in this room today and recognize my Faustian plight. Gil told us we could do it, that it was our moral duty to our country, to our families, to our own happiness, to unborn generations of students, etc., etc., etc. And besides that, he offered one of the GAS cans he had purchased and his full support. Gil jokingly tells new participants in his projects that you have surrendered your soul to the enterprise.... he's not joking.

Perhaps Gil's greatest achievement has been that he has cloned himself in the person of Bob Twiggs. Bob now leads, guides, cajoles, threatens, encourages, commits, supports, etc. the Center for AeroSpace Technology at Weber State College in much the same way Gil did during the NUSAT I project.

I believe the opportunities to find government sponsors and advocates are almost limitless. Many of you were at the DARPA/AIAA sponsored conference on LightSats at the Naval Post-Graduate School in Monterey, CA, last August and at the Conference on Small Satellites sponsored by Utah State University and the AIAA in Logan, Utah, earlier this month. You may have been as surprised as we were at the tremendous range of interest and potential applications of small low earth orbit satellites. The government was represented by every branch of the Department of Defense, the Department of Transportation, the Federal Communications Commission, the Department of Energy, the National Aeronautics and Space Administration and probably some more we didn't meet.

Several people in the FAA are now interested in using small, low earth orbit satellites to implement some of the programs identified in the Research, Engineering and Development Plan. These include: providing accurate, current, over ocean aircraft positions to air traffic controllers; enhancing low altitude and off-shore communications capabilities; monitoring and controlling remote facilities; and dependent surveillance systems.

Similar systems are of interest to other government organizations. We know the Federal Communications Commission is interested in the solution of a problem common to the FAA and several military groups. We know that many other government organizations maintain remote communications and sensor facilities that require monitoring and control including: the Department of Defense, the Bureau of Land Management, the Department of Engergy, the National Park Service, the National Oceanic and Atmospheric Administration, the United States Coast Guard, the National Forest Service, the National Weather Service, the Secret Service, the Drug Enforcement Administration, the Immigration and Naturalization Service, the Department of Agriculture, the Federal Bureau of Investigation, the Department of Transportation, the United States Fish and Wildlife Service, the United States Geological Survey, etc. These are just a few I have worked with from time to time and now have remote facilities and communications requirements.

I'm sure that many of you know of applications and experiments or demonstrations of great interest to these, and other, agencies. In addition, international, state and local governments have many agencies which parallel the Federal agencies. Utilities, oil companies, railroads, shipping companies, engineering companies, etc. and associations of these companies offer opportunities similar to government agencies.

In conclusion, I hope I have convinced you there are many advantages to be realized from government sponsorship of GAS projects, both to the sponsor and the sponsored. I hope I have given you some useful insight on how to win friends and influence people among your public servants. And I hope I have inspired some of you to seek new applications of the GAS resource which will benefit us all.

I appreciate the opportunity our hosts have given me to address you and your kind attention. Thank you.

** PRELIMINARY **

GAS ELEVEN NODE THERMAL MODEL (GEM)

Dan Butler   October 1987

INTRODUCTION

The Eleven Node Thermal Model (GEM) of the Get Away Special (GAS) container was originally developed based on the results of thermal tests of the GAS container. The model was then used in the thermal analysis and design of several NASA/GSFC GAS experiments, including the Flight Verification Payload (FVP), the Ultra-Violet Experiment (UVX), and the Capillary Pumped Loop (CPL).

The enclosed model description details the five cubic foot container both with and without an insulated end cap. Mass specific heat values are also given so that transient analyses can be performed. A sample problem for each configuration is included as well so that GEM users can verify their computations. The model can be run on most PC size computers with a thermal analyzer solution routine.

CONTAINER WITH THE INSULATED END CAP

The thermal model for the container with the insulated end cap is presented in Figure 1 with a nodal listing given in Table 1. The container cylinder is represented by three nodes, and the top and bottom end plates have one node each. The side insulation is represented by one node and the end caps have two nodes each. The external environment (node 11) represents the boundary condition for the model. This is a fixed (constant) temperature node which is set to a temperature level obtained from the GAS container equilibrium temperature table given on page 67 of the GAS experimenter handbook (Red book - reference 1). These boundary conditions were determined by extensive computer analysis and flight data.

The conduction couplings for the model are given in Table 2. Additional couplings may be added depending on the unique payload configuration being modeled, such as payload couplings to the top mounting plate (node 1). The conductive coupling from the GAS container to the GAS adapter beam is not included in the interest of simplifying the model. Furthermore, fiberglas isolators reduce the thermal conductance to a minimum in this area.

The external radiative couplings are given in Table 3. These values represent the radiative couplings from the container through the insulation system to the external environment. These values stay fixed regardless of the internal payload configuration.

The internal radiative couplings for an empty container with no payload are given in Table 4. These values were determined by the geometrical view factor program contained in the Simplified Shuttle Payload Thermal Analyzer (SSPTA). The calculations were based on GAS container internal dimensions of 20 inches in diameter by 31.25 inches long. The internal surface emittance of the container is 0.80 (anodized aluminum). It should be noted that the internal radiative couplings will change dramatically when a payload is introduced into the container as will be shown in the following example.

EXAMPLE PROBLEM 1

A cylindrical experiment payload is mounted to the experiment mounting plate with conductive isolators. It is 15.5 inches in diameter by 28 inches long and painted black (surface emittance is 0.85). The payload is represented by node 12 in Figure 2 and Table 1. This is the same example payload that was used in the GAS Motorized Door Assembly (MDA) Thermal Design Guide (reference 3).

Since this payload is conductively isolated from the experiment mounting plate, no additional conductive couplings are required. However, there are large modifications to the internal radiative couplings as shown in Table 5, due to the influence of the experiment payload. These couplings replace the radiative couplings given in Table 4. The radiative couplings were again determined using the SSPTA program, although they had to be modified from the MDA thermal analysis to correspond to the nodal breakdown of the GAS Eleven Node Model (GEM). The radiative couplings may be hand calculated or estimated if necessary, however, this can be somewhat tedious and inaccurate depending on the complexity of individual payload thermal models.

Three thermal environment cases were run for the example problem with payload power levels set at 10 watts and 25 watts. Table 6 gives the steady state temperature results for both the average container temperature (Node 3) and the payload temperature (Node 12) for the moderately cold, earth viewing (ZLV), and hot cases. These cases refer to the thermal environments listed on page 67 of the GAS red book for the 5 cubic foot container with the insulated end cap. Temperature levels are also given for the same payload covered with low emittance aluminum tape. For this case, the radiative couplings to node 12, numbers 23 through 27, are reduced to 0.06 times their original value, corresponding to an aluminum tape emittance of 0.05. A substantial payload temperature increase results from this change, even though the container temperature is unaffected.

The average container temperatures listed in Table 6 correspond to node 3, which is an approximate average of nodes 1-5 for this configuration. None of the container temperatures varied by more than 0.5 degrees C in this case. Other payloads having large conductive couplings to the experiment mounting plate (node 1) would yield greater temperature variations within the container.

A comparison between GEM and the 3-node thermal model described in the GAS Thermal Design Summary (reference 2) was also performed. The GAS container temperature curves shown on pages 69 through 72 of the GAS red book were produced utilizing the 3-node model. The GEM average container temperatures from Table 6 are indicated on Figure 3, which is excerpted from page 69 of the red book. Both models agree fairly well, although GEM predicts slightly warmer temperature levels in all cases. This may result from the omission of the conduction coupling from the GAS container to the adapter beam in GEM, which yields a slightly lower overall container heat loss to the environment. Although this conduction coupling is not directly included in the 3-node model, its effect was included in its overall heat transfer coefficient to the environment (effective emittance). It was decided to leave GEM as is rather than increase its thermal coefficients to compensate for the difference. Recent indications such as Dr. Werner Neupert's report (reference 4) suggest that the thermal coefficient (effective emittance) in the 3-node model may be too high. Other flight results tend to confirm this as well. If GEM were reduced to the 3-node model, the effective emittance would be reduced to 0.056 as

stated in the Thermal Design Summary (ref. 2). Final resolution of this discrepancy would require additional thermal tests of the GAS container in its latest configuration.

GEM TRANSIENT CONSIDERATIONS

EXAMPLE 2

The mass specific heat values for GEM are given in Table 7. This information is required in order to perform transient thermal analyses with GEM. The experiment payload from the previous example (node 12) is included as a 165 pound payload with a specific heat of 0.21 BTU/LB-deg R. This configuration was run for the cold, earth viewing, and hot-33 cases described in Table 1 of the GAS/MDA thermal design guide (ref. 3). The environment temperature (node 11) was set to the corresponding levels listed in Table 2 of the MDA guide. The conductive and radiative thermal couplings are the same as those from the previous example for a black painted experiment payload. The transient temperature results for a 48 hour no power case are given in Table 8, with average container (node 3) and experiment payload (node 12) temperatures listed. The payload temperatures are then plotted on Figure 4, which is excerpted from the MDA guide. This plot gives a comparison between the GEM container model and the SSPTA closed door MDA model. The two models agree quite well, showing the thermal similarity between the closed GAS/MDA container and the standard container with the insulated end cap. GEM runs slightly warmer than the GAS/MDA model, which may again be due to the omission of the conductance to the adapter beam as discussed previously.

EXAMPLE 3

Another comparison was run for the transient cooldown of the GAS/EMP experiment on the STS-61C mission. This time a comparison between GEM and actual flight data was made. The EMP was a 200 pound payload that was conductively isolated from, but radiatively coupled to the GAS container. EMP was modelled in an approximate fashion using the same experiment payload model cited in the previous examples. The radiative and conductive couplings were left unchanged, but the mass specific heat of node 12 was increased to 42.0 BTU/deg R, assuming a payload specific heat of 0.21 BTU/LB-deg R. The first 24 hours of the mission were simulated. The starting temperature was 19.5 C and node 11 was set at -5 C (earth viewing environment) for the first 12 hours and to -50 C (moderately cold condition) for the next 12 hours. Table 9 gives the transient temperature results for the average container (node 3) and the experiment payload (node 12) thermal levels. (Note that this is a no power cooldown condition). The GEM payload temperatures (node 12) are indicated on Figure 5 which is the EMP temperature profile for STS-61C (ref. 5). Excellent agreement between the GEM predictions and actual flight results is demonstrated. Figure 5 also shows that after the EMP reached 7 deg C, its heaters began to cycle to maintain its temperature near 7 C throughout a variety of shuttle thermal conditions. This is an example of the tight thermal control that can be achieved with the use of thermal control heaters and thermostats.

CONTAINER WITHOUT THE INSULATED END CAP

The GAS container without the insulated end cap is easily modelled by making minor modifications to GEM. Nodes 9 and 10 representing the top insulated end cap

149

are removed as shown in Figure 6. GEM now becomes the GAS Nine node Model, or GNM.
The conductive and radiative couplings associated with nodes 9 and 10 are also re-
moved, and a radiative coupling between the top mounting plate (node 1) and the en-
vironment (node 11) is added. Specifically, conductive couplings #5 and #8 are re-
moved from Table 2 and radiative couplings #1, #2, #11, and #12 are removed from
Table 3. A radiative coupling from node 1 to node 11 with a value of 2.34 FT**2
should be added to Table 3. For the transient model, the mass specific heat values
for nodes 9 and 10 should be removed from Table 7.

EXAMPLE 4

GNM was run using the same experiment payload model (node 12) that was used
for the previous examples. The moderately cold, earth viewing (ZLV), and hot cases
were run for experiment power levels of 10, 25, and 50 watts. Node 11 was set to
the corresponding boundary temperatures listed on page 67 of the GAS red book for
the 5 cubic foot container without the insulated end cap. Steady state temperature
results for the container top plate (node 1), the average container temperature
(node 3), and the experiment payload (node 12) are listed in Table 10. Much
larger gradients are evident throughout the GAS container as compared to the GEM
values. The power levels required to maintain a specific payload temperature level
are higher too. This shows that a container without the insulated end cap is best
suited for those experiments that have high continuous power dissipations and/or
desire lower temperature levels.

The average container temperatures (node 3) of GNM were compared to the 3 node
model (ref. 2) as well. Figure 7 shows the GNM container temperatures from Table
10 plotted on the temperature curves excerpted from page 71 of the GAS red book for
the container without the insulated end cap. GNM, like GEM predicts slightly
warmer temperatures that the 3 node model, although reasonable agreement is evident,
especially at the lower power levels. The reason for the discrepancy is probably
due to the container-to-top-plate thermal gradient, which becomes especially pro-
nounced at higher power levels. The 3 node model does not show this since it gives
only an average temperature for the entire container. The effect of the lack of
conductance to the adapter beam is very minor in this case due to the large dominant
radiative coupling from the container top plate to the environment.

GNM TRANSIENT CONSIDERATIONS

EXAMPLE 5

Transient cooldown cases (no power) were run for the previous example problem
for the cold and earth viewing (ZLV) cases. Table 11 gives the transient temper-
ature results for nodes 1, 3 and 12 for a 48 hour cooldown. Node 11 was
ARBITRARILY set to the boundary conditions used in Table 8 for the GEM transient
case of example 2, so that a comparison could be made between GEM and GNM. Thus,
a comparison of the two container configurations was accomplished, showing the
different transient thermal behavior of each. For YOUR thermal analysis and design,
node 11 should be set to the boundary conditions listed on page 67 of the red book
for the 5 cubic foot container without the insulated end cap.

Figure 8 is a plot of the average container temperature (node 3) from GEM and
GNM for the cold and earth viewing (ZLV) cases. These curves show that the con-
tainer without the insulated end cap responds much more quickly to a given thermal

150

environment, further demonstrating the different thermal behavior of the two container configurations. The 2-node transient model described in the GAS Thermal Design Summary (reference 2) was also analyzed for these cases. The results of this analysis are indicated on Figure 8. The agreement with GEM is good, but comparison with GNM shows that with GNM predicts warmer temperatures than the 2-node model. The 2-node model does not include the influence of large thermal gradients within the container that result from the removal of the insulated end cap. GNM should therfore be inherently more accurate than the 2-node model, which only provides a bulk or average container temperature.

CONCLUSIONS

Thermal models of the GAS container both with and without an insulated end cap have been presented. Examples have been provided for each case so that users can verify their thermal computations. This information should assist those GAS users that require more accurate thermal analyses than that previously available from the smaller models. This information is especially pertinent to the container without the insulated end cap, since large thermal gradients can exist within the container.

Users are cautioned that this model is NOT perfect or exact. Unique payload configurations and variations in shuttle orbits can affect the thermal environment substantially. A +/- 10 deg C uncertainity should be applied to the listed temperatures, and payloads should be designed with enough margin to overcome these and other uncertainities.

<p align="center">GOOD LUCK WITH YOUR THERMAL DESIGN</p>

REFERENCES

1. "Get Away Special (GAS) Experimenter Handbook" (Red Book), 1987, NASA/GSFC Special Payloads Division

2. "Get Away Special (GAS) Thermal Design Summary" by Dan Butler, NASA/GSFC X-732-83-8, July 1983

3. "Thermal Design Guide for Get Away Specials/Motorized Door Assembly Users" by Anthony Melak, Swales and Associates and Dan Butler NASA/GSFC, September 1986

4. "Response of GAS Payload (G345 and G347) Temperatures to Various Orbiter Flight Attitudes" by Dr. Werner M. Neupert, NASA/GSFC GAS Symposium, October 1985

5. "Temperature Data from Selected GAS Flights" Dan Butler, NASA/GSFC GAS Symposium, October 1986

THERMAL ANALYZER PROGRAMS FOR THE PC

1. PC SSPTA   Frederick A. Costello Inc.
                12864 Tewksbury Dr.
                Herndon, VA 22071
                Phone: (703) 620-4942

2. PC SINDA   Jerry GASKI
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                Los Angeles, CA 90041
                Phone: (213) 259-3888

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TABLE 1

GAS ELEVEN NODE THERMAL MODEL (GEM)

NODAL LISTING

1. Container Top - Experiment Mounting Plate

2. Cylinder Upper Section

3. Cylinder Middle Section

4. Cylinder Lower Section

5. Container Bottom - Interface Equipment Plate

6. Bottom Insulated End Cap Disc

7. Bottom Insulated End Cap Side

8. Container Side Insulation

9. Top Insulated End Cap Side

10. Top Insulated End Cap Disc

11. Thermal Environment

12. Example Experiment Payload

TABLE 2

GEM CONDUCTION COUPLINGS

NUMBER	COUPLING	VALUE (BTU/deg R)
1	1 - 2	10.08
2	2 - 3	6.63
3	3 - 4	6.63
4	4 - 5	10.08
5	1 - 9	0.08
6	5 - 7	0.08
7	6 - 7	0.02
8	9 - 10	0.02

TABLE 3

GEM EXTERNAL RADIATION COUPLINGS

NUMBER	COUPLING	VALUE (FT**2)
1	1 - 9	0.06
2	1 - 10	0.06
3	2 - 8	0.34
4	3 - 8	0.34
5	4 - 8	0.34
6	5 - 6	0.06
7	5 - 7	0.06
8	6 - 11	2.53
9	7 - 11	0.72
10	8 - 11	13.97
11	9 - 11	0.72
12	10 - 11	2.53

TABLE 4

GEM INTERNAL RADIATION COUPLINGS

NO PAYLOAD - EMPTY CONTAINER

NUMBER	COUPLING	VALUE (FT**2)
13	1 - 2	1.17
14	1 - 3	0.29
15	1 - 4	0.16
16	1 - 5	0.15
17	2 - 3	0.67
18	2 - 4	0.31
19	2 - 5	0.16
20	3 - 4	0.67
21	3 - 5	0.29
22	4 - 5	1.17

TABLE 5

GEM INTERNAL RADIATIVE COUPLINGS

EXAMPLE EXPERIMENT PAYLOAD (NODE 12)

NUMBER	COUPLING	VALUE (FT**2)
13	1 - 2	0.61
14	1 - 3	0.06
15	1 - 4	0.01
16	1 - 5	0.01
17	2 - 3	0.10
18	2 - 4	0.02
19	2 - 5	0.01
20	3 - 4	0.10
21	3 - 5	0.05
22	4 - 5	0.62
23	1 - 12	1.18
24	2 - 12	2.39
25	3 - 12	2.39
26	4 - 12	2.39
27	5 - 12	0.88

TABLE 6

GEM STEADY STATE TEMPERATURES (DEG. C)

EXAMPLE 1

	MODERATELY COLD	EARTH VIEWING	HOT
ENVIRONMENT	-50.0	-5.0	40.0
POWER = 10 WATTS			
CONTAINER	-24.1	12.1	51.6
PAYLOAD (BLACK)	-20.8	14.3	53.1
PAYLOAD (AL TAPE)	18.9	43.4	74.1
POWER = 25 WATTS			
CONTAINER	5.0	33.3	66.9
PAYLOAD (BLACK)	10.8	37.6	70.1
PAYLOAD (AL TAPE)	74.2	89.9	111.7

TABLE 7

GEM MASS SPECIFIC HEATS (MCP's)

TRANSIENT MODEL

NODE	MCP (BTU/deg R)
1	5.78
2	4.77
3	4.77
4	3.56
5	7.67
6	1.47
7	0.49
8	0.93
9	0.49
10	1.33
11	N/A
12	34.6

Note: Nodes 2 and 3 contain additional mass due to the GAS container support brackets.

TABLE 8

GEM TRANSIENT TEMPERATURES (DEG C)

EXAMPLE 2

	COLD		EARTH VIEWING		HOT	
ENVIRONMENT	-75.8		-8.9		45.2	
TIME (HRS)	CONTAINER	PAYLOAD	CONTAINER	PAYLOAD	CONTAINER	PAYLOAD
0	20.0	20.0	20.0	20.0	20.0	20.0
8	8.8	13.2	15.4	17.2	25.4	23.6
16	1.0	5.1	12.2	13.8	28.8	27.3
24	-5.8	-1.9	9.5	10.9	31.7	30.5
32	-11.8	-8.0	7.2	8.5	34.1	33.1
40	-17.0	-13.5	5.2	6.3	36.0	35.2
48	-21.7	-18.4	3.5	4.4	37.7	37.0

TABLE 9

GEM TRANSIENT TEMPERATURES (DEG C)

EXAMPLE 3

TIME (HOURS)	CONTAINER	PAYLOAD
0	19.5	19.5
4	17.0	18.7
8	15.4	17.2
12	14.0	15.7
16	9.8	13.4
20	6.8	10.5
24	4.0	7.6

NOTE: The environment temperature (node 11) was held at -5 deg C for hours 0 - 12 and at -50 deg C for hours 12 - 24.

TABLE 10

GNM STEADY STATE TEMPERATURES (DEG C)

EXAMPLE 4

	MODERATELY COLD	EARTH VIEWING	HOT
ENVIRONMENT	-55.0	-10.0	25.0
POWER = 10 WATTS			
TOP PLATE	-43.5	-3.1	29.8
CONTAINER	-41.9	-1.7	31.1
PAYLOAD	-38.1	0.6	32.7
POWER = 25 WATTS			
TOP PLATE	-29.1	6.0	36.3
CONTAINER	-25.3	9.5	39.5
PAYLOAD	-17.8	14.4	43.1
POWER = 50 WATTS			
TOP PLATE	-9.8	19.4	46.3
CONTAINER	-2.6	26.0	52.3
PAYLOAD	8.4	34.1	58.6

TABLE 11

GNM TRANSIENT TEMPERATURES (DEG C)

EXAMPLE 5

	COLD			EARTH VIEWING		
ENVIRONMENT	-75.8				-8.9	
TIME (HRS)	TOP PLATE	CONTAINER	PAYLOAD	TOP PLATE	CONTAINER	PAYLOAD
0	20.0	20.0	20.0	20.0	20.0	20.0
8	-11.2	-2.4	5.4	7.4	10.9	13.8
16	-22.6	-15.7	-8.5	3.2	5.7	8.0
24	-31.3	-25.8	-19.4	0.1	2.0	3.8
32	-38.2	-33.7	-28.0	-2.1	-0.7	0.7
40	-43.8	-40.1	-35.0	-3.7	-2.7	-1.7
48	-48.4	-45.3	-40.7	-5.0	-4.2	-3.4

NOTE: The environment temperature (node 11) was arbitrarily set to the temperatures shown for comparison purposes only. GNM users should set node 11 to the environment temperatures listed on page 67 of the GAS red book for the container without the insulated end cap.
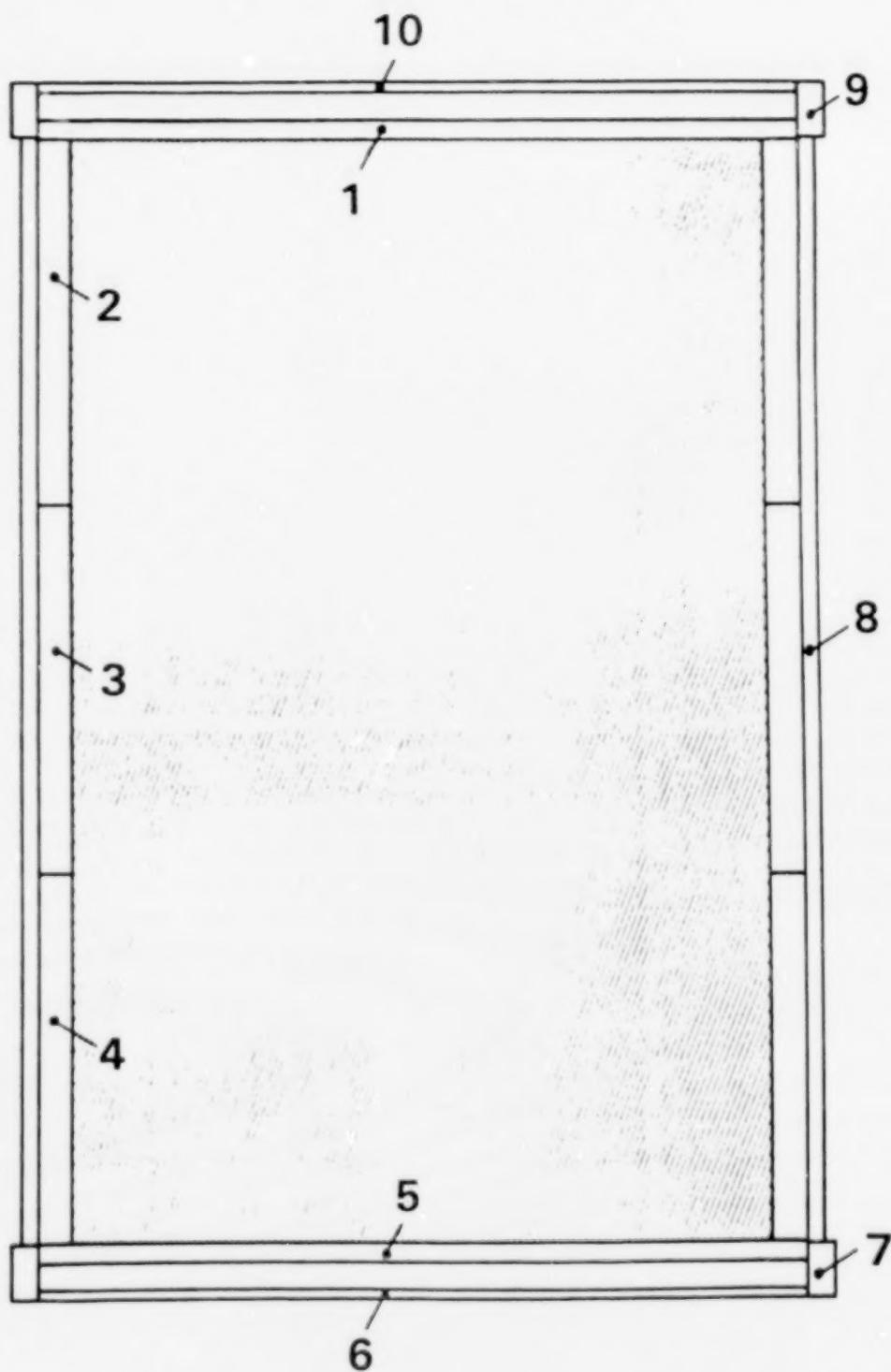
Figure 1. GAS 5 ft^3 Container Thermal Model (with Insulated End Cap)
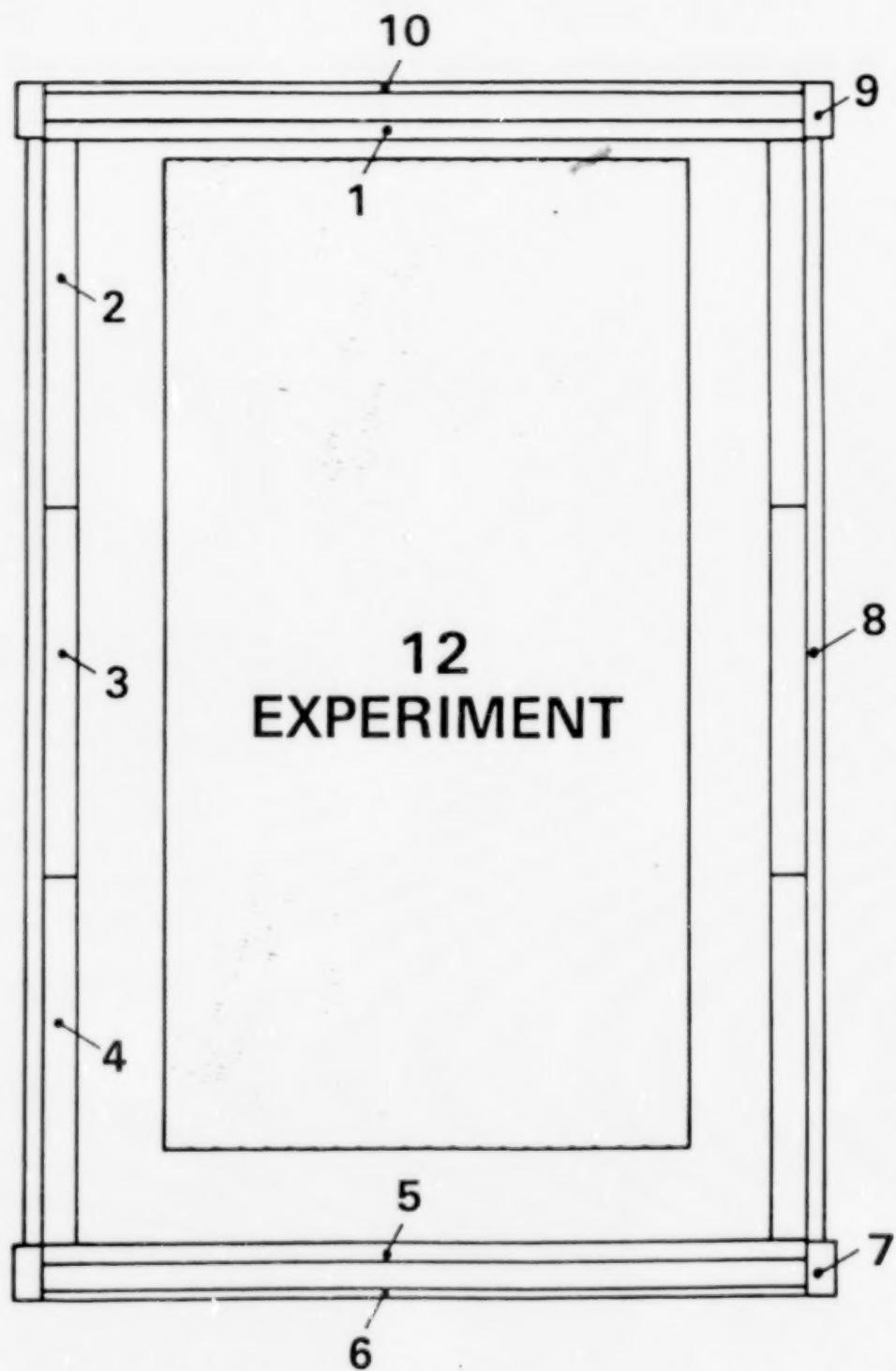
Figure 2. GAS 5 ft^3 Container Thermal Model (with Insulated End Cap)
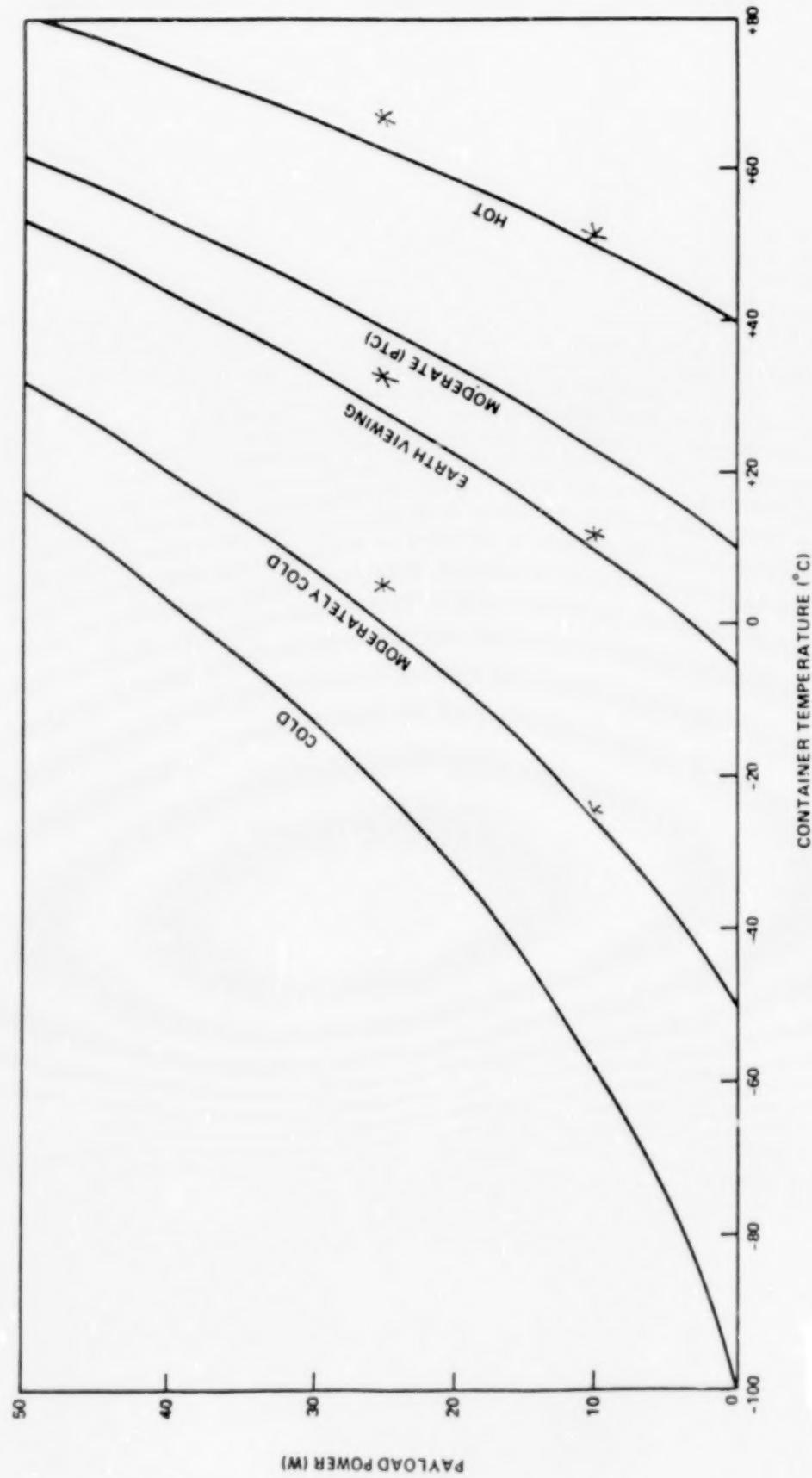
Figure 3. Get Away Special Small Self-contained Payloads (5 ft³ Container with Insulated End Cap)
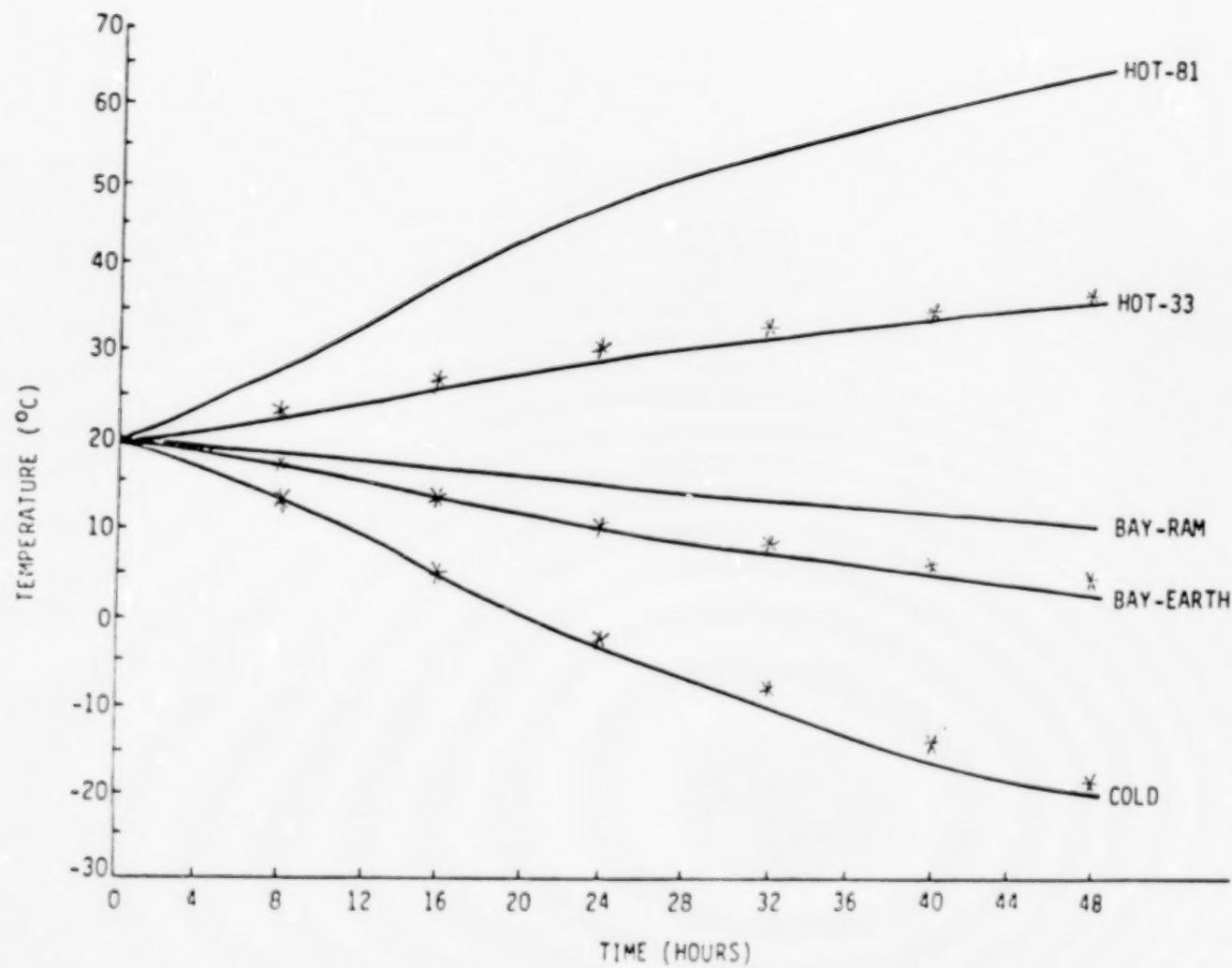
Figure 4. Closed GAS/MDA Experiment Transient Temperature Response for Zero Power

Figure 5. EMP Temperature Results STS 61-C, January, 1986
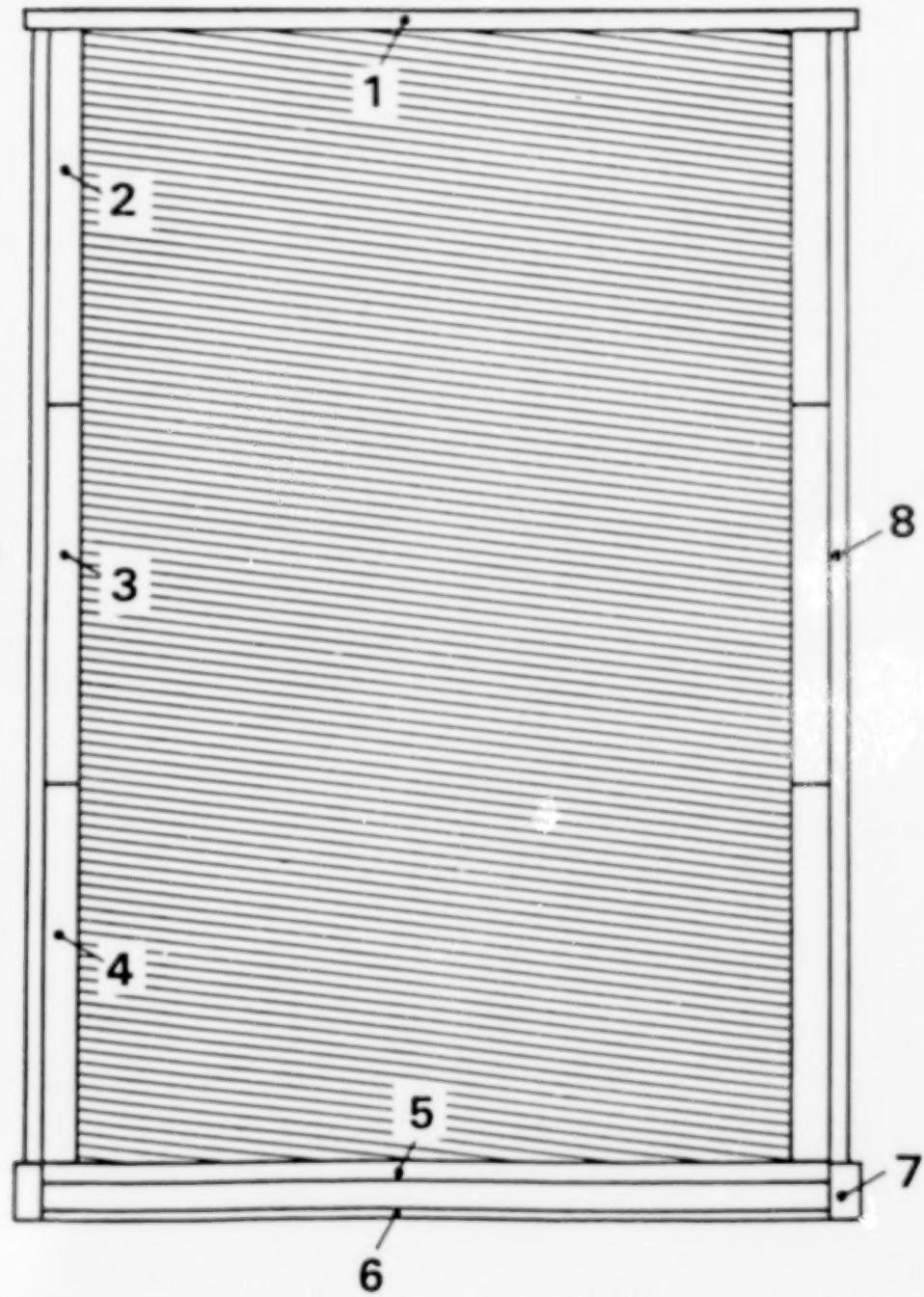
Figure 6. GAS 5 ft³ Container Thermal Model (without Insulated End Cap)
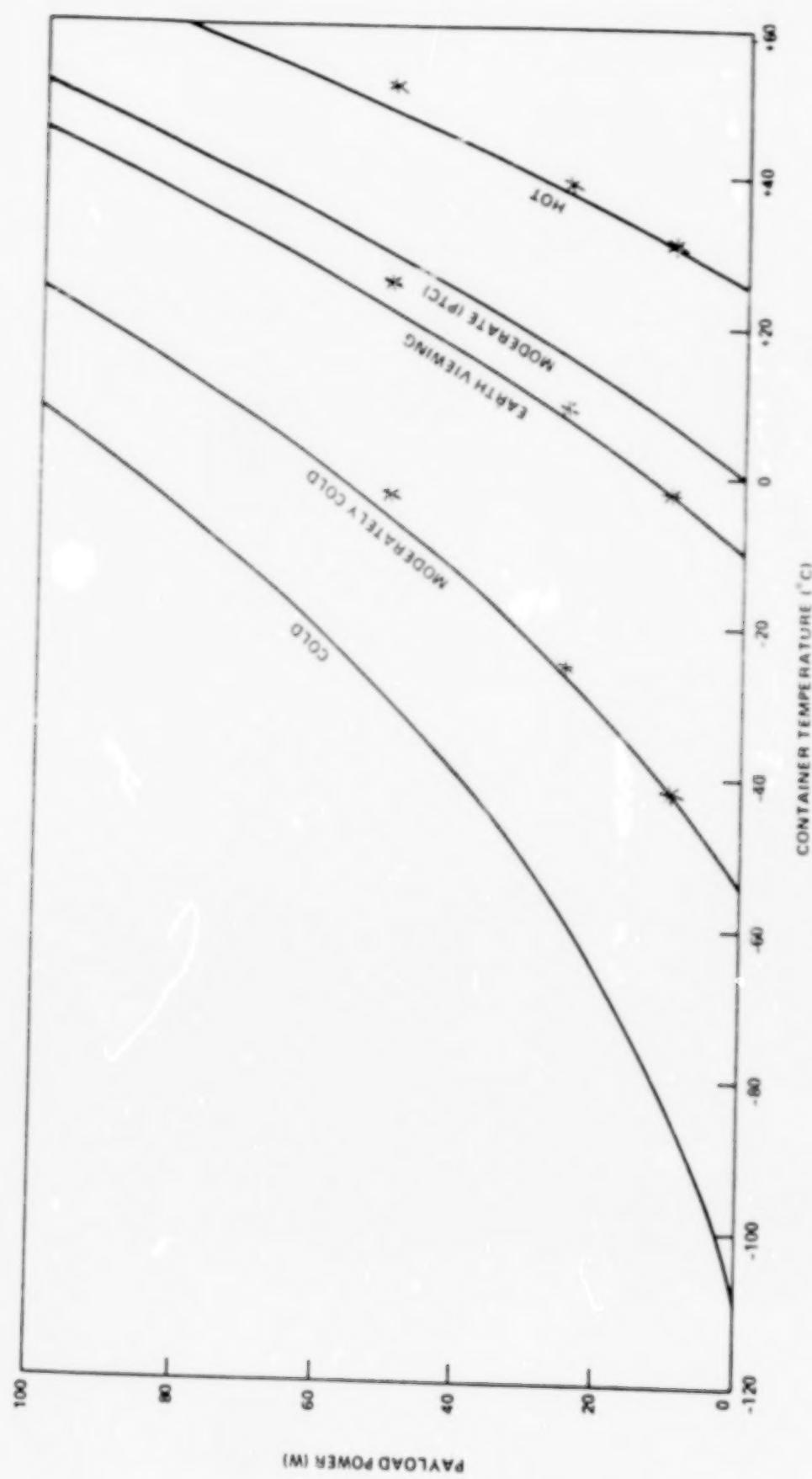
Figure 7. Get Away Special Small Self-contained Payloads (5 ft³ Container without Insulated End Cap)
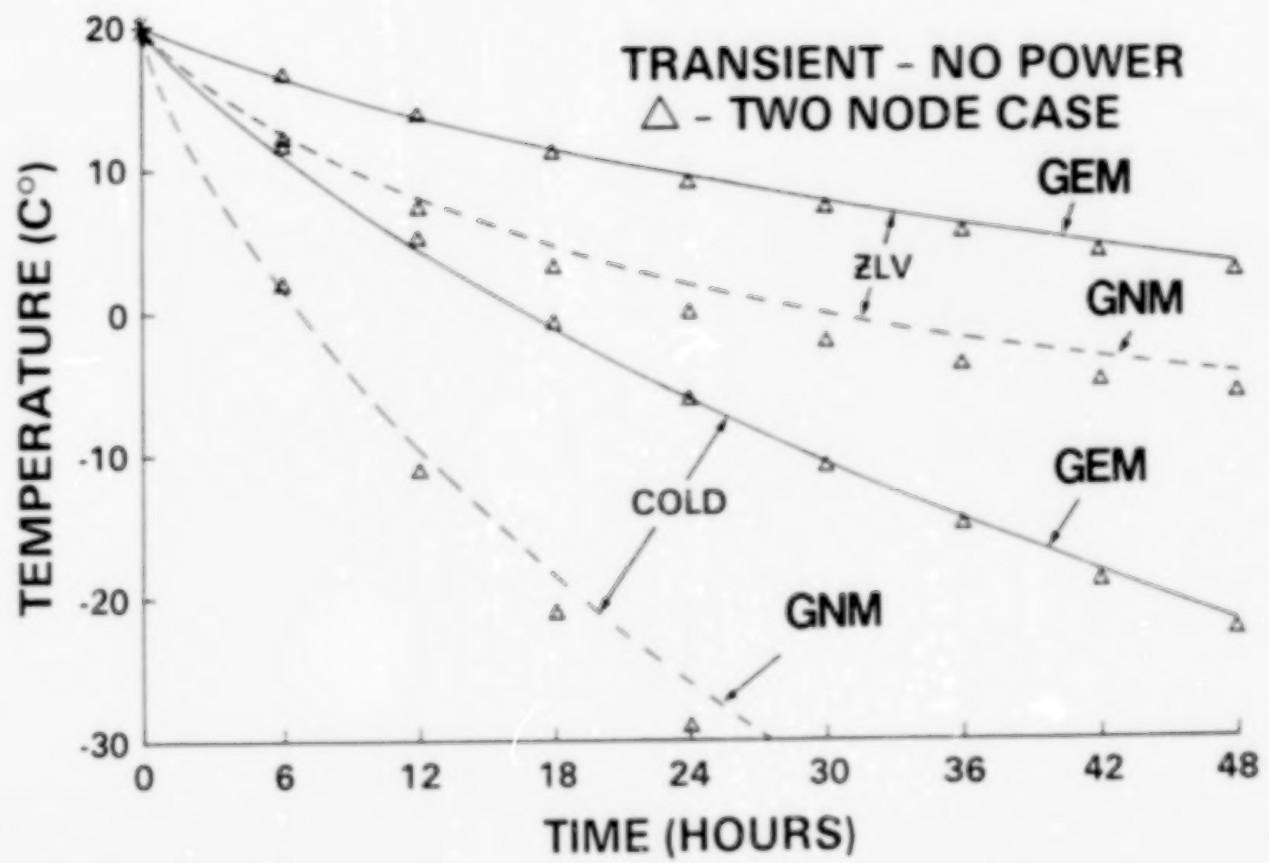
Figure 8. GAS M⌐ dels with 165# Payload Container Temperatures

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15. Supplementary Notes

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16. Abstract

The 1987 Get Away Special (GAS) Experimenter's Symposium will provide a formal opportunity for GAS Experimenters to share the results of their projects. The focus of this symposium is on payloads that have been flown on Shuttle missions, and on GAS payloads that will be flown in the future.

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